caecomments | 02

DISTRIBUTED GENERATION | *A STUDY OF OPPORTUNITIES*

foreword

Distributed generation (DG) has emerged as both a potentially attractive means of providing new electricity generating capacity and an alternative to expanding the capacity of established electricity transmission and distribution networks. This situation has arisen because of the ongoing improvement in the technologies used in DG and also because of the changing structure of the electricity industry, which now encourages more innovative solutions to meet energy requirements involving a number of industry stakeholders.

This commentary is the summary of an extensive technical evaluation undertaken by the Centre for Advanced Engineering (CAE) of DG opportunities in New Zealand. The study was commissioned by industry partners and is intended to chart the likely development of DG within the context of the New Zealand electricity industry. The analysis framework uses data from actual case studies of DG projects, some of which have been successfully implemented, others not, to demonstrate the viability of DG under different circumstances. The analysis timeframe is out to the year 2015.

Much of the technology that falls under the rubric of DG is not new and has to some extent already been adopted in New Zealand. In fact, as the CAE studies have shown, DG is more widespread and entrenched than generally recognised, yet despite obvious financial and risk management drivers for DG, investment in DG to date has been essentially opportunistic, and the benefits of DG have been difficult to realise.

This commentary tests the hypothesis 'that distributed generation now permits a paradigm shift in thinking about solutions for meeting consumer energy capacity and reliability requirements'. The key to DG's future will be migrating from current strategies into a new energy market focused on customer solutions rather than utility responses. This commentary defines how DG might emerge in the future and identifies the strategies required to make it happen. The task now is to reveal DG opportunities and encourage projects offering mutual benefit and opportunity to be developed jointly by suppliers and consumers.

This will set the scene post-2015 for emerging energy technologies to build on the strength of the proven technologies. These challenges will form the basis for future CAE programmes.

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executive summary

DISTRIBUTED GENERATION: THE OPPORTUNITY

Distributed generation (DG) permits a paradigm shift in thinking about delivering local solutions for meeting individual consumer energy needs.

DG has the potential to:

- reduce the supply-demand gap emerging in New Zealand's electricity supply
- contribute up to 50% of anticipated annual future electricity demand increases
- provide an alternative to expanding the capacity of established electricity transmission and distribution networks
- alleviate constraints on new hydro development and natural gas supply by providing a more diverse energy base for electricity generation.

New Zealand need no longer rely on utility solutions and industry trading arrangements to meet expanding electricity supply requirements. Instead, DG creates niche opportunities, with customised solutions and improved access to reliable electricity supply. DG can fundamentally change investments at all levels of the electricity supply network.

There are many possible configurations for the application of DG:

- cogeneration plant at industrial or commercial sites
- stand-by generation using diesel, gas, coal, geothermal and other fuel sources
- generation plant supplying directly into local distribution networks, such as wind farms
- micro-grid (islanded) operation
- electricity storage devices to meet demand peaks
- fuel switching at times of system peaks
- demand side management systems.

DG will be most useful in providing a more diverse energy base for electricity generation, and indirectly, enable better management of established hydro storage. DG is also a means of utilising generation from renewable energy sources such as hydro and wind in situations that would otherwise not be economic if supplied into the central grid. In the investment environment of the future, regulatory measures aimed at greenhouse gas reduction are likely to benefit almost all DG opportunities.

DG provides local solutions to local energy needs and the benefits – economic, social and environmental – are directly transferable to local communities.

OBSTACLES AND CONSTRAINTS

In general, there are three principal objectives of DG investment:

- to extend energy supply by installing local generation capacity
- to complement expansion of network capacity by deferring or obviating the need to increase the capacity of transmission or distribution lines
- to hedge electricity prices as a risk management strategy for consumers against increasing price.

From an economic perspective, the use of DG has clear attractions. Deregulation of the electricity sector has already accelerated investment and development of smaller electricity generating plants embedded in distribution networks, but the current DG market is under-exploited. The environmental and social benefits of DG are often not recognised, and the difficulties of obtaining resource consents have a serious impact on the potential DG investor and add to overall costs. At the forefront of the factors constraining the use of DG are technical issues, but standing alongside these are many commercial and regulatory issues.

The New Zealand electricity market is characterised by few significant load centres and a widely dispersed, lightly loaded, rural network. One percent of all New Zealand electricity customers account for 70% of the total industrial and commercial electricity consumption. Fewer than 150 users have loads within the 1- 5 MW scale, typical of conventional distributed generation modes, and New Zealand is likely to embrace systems of less than 1 MW capacity – quite different from many other developed countries. At this scale, distributed generation is likely to be less technically feasible than alternative energy efficiency options, and questions of system adequacy are likely to be more important than reduced energy consumption.

DG is widely perceived to constitute a threat to the conventional participants in the electricity industry. In reality, it presents an opportunity to better allocate supply and price risk in an increasingly volatile energy market. Maximising this opportunity will require more innovative engineering and contractual solutions.

The variability of all renewable sources of DG, apart from geothermal, means that for some time yet New Zealand will probably be reliant on fossil fuels to meet peak demand. Renewable energy types of DG will need government support and will remain a small contributor. Non-renewable energy types of DG will face government disincentives and yet have the greatest potential.

CRITICAL SUCCESS FACTORS

Most DG to date has been developed by using established technologies such as reciprocating engines, combustion turbines and small hydro. Developing technologies have yet to approach mature market costs. In all probability, potential in New Zealand for DG up to 2015 will use existing technology and some additional wind power. Developments beyond then will be driven as much by the industry structure of the day and its modus operandi as by the technologies available.

DG is not a replacement for electricity supplied through the wholesale market. Rather, DG is a different market, complementary to the wholesale market, with each providing different cost structures and benefits. For example, a secondary DG market can be envisaged involving on-selling or buy-back of surplus electricity capacity. Innovative solutions are often needed to realise such interdependent activities, in both technical and contractual contexts.

In order for DG and demand-side management to be effective, it will be necessary to employ the technologies of the information age. The focus of DG uptake is not about the technologies of conversion, but about the enabling technologies of two-way communication to every customer and plant item on the network using real-time pricing, smart metering, and high-level modelling of the electricity system. It is these enabling technologies that will herald significant changes in supply structures.

The issues that will influence DG uptake centre on dealing with the complexity of the number and type of energy sources, changes in electricity transmission flows, maintenance of local reliability and security, and market integration.

THE FUTURE DG MARKET

DG applications are highly localised niche arrangements. Business relationships typically are more complex than in wholesale market situations. Although the objectives and interests of electricity suppliers and consumers may be apparently different, the benefits are often synergistic and the boundaries between the activities each party can become indistinct.

The regulatory regime required is one that does not skew investment efficiency but instead levels the playing field so that grid-based generators are not favoured over DG and demand-side management opportunities.

The future DG market can best be described as an engineered outcome driven around market needs. The critical characteristics of the future DG market are:

- matching changes in demand and supply capacity of networks in a more efficient way
- providing specialised energy products and services direct to customers
- using smaller and potentially more fuel-efficient plant requiring lower capital investment
- providing environmental benefits from efficient fuel-to-energy conversion
- taking up the opportunity of fuels that are essentially free, such as wood waste and landfill gas
- serving multiple purposes such as in combination with irrigation schemes, to defer asset investment, or to demonstrate new technology
- providing alternatives to customer dissatisfaction with existing market access arrangements.

There are three possible routes in the near term:

- a continuation of current trends based on embedded generation using conventional technologies and supplemented by limited additional investment in co-generation
- a second investment stream of small-scale renewable energy generation facilitated by supportive government policy and market mechanisms
- a future 'engineered' market driven by capacity and access arrangements, and characterised by information and key electronic technologies required for sophisticated electricity supply management and control to every customer.

These routes overlap and can merge together or they can remain separate, but the establishment of an active 'engineered' market will be an essential condition for realising the full potential of DG opportunities. The task is now to reveal DG and demand-side opportunities and encourage the development of co-operative projects by suppliers and consumers through use of essential enabling technologies.

introduction

THE ORIGIN OF THIS COMMENTARY

In 2000, CAE was commissioned to undertake a thorough analysis of the business processes for investment in DG and evaluate the technological and regulatory climate likely to govern DG investment in New Zealand. The study was intended to:

- develop a better understanding of the potential for DG in New Zealand and in particular the circumstances under which DG is most likely to be deployed
- facilitate the assessment of opportunities for establishing DG
- describe the implications on operation and configuration of the New Zealand electricity system arising from the wide-scale introduction of DG
- outline the market influences, international technology trends and externalities that will impact on the actual scale of DG uptake.

New Zealand is not alone in its interest in DG. There is a strong international effort through research and investment into DG applications that involve not only technology development, but also energy network/distribution responses to meeting future energy needs. The lesson that can be taken from this experience is that DG implementation is by no means straightforward. The economic feasibility of many DG applications has yet to reach levels to lead to wide-scale uptake. Regulatory requirements have yet to be developed to match the technology, and distribution networks are still far from sufficiently developed to allow DG to participate effectively in the marketplace.

International experience suggests that a great deal more work needs to be done if DG is to become a serious source of energy supply in the near future. The overriding issue is that DG is not yet fully valued in the energy market. While some niche markets are emerging for DG in New Zealand, it is clear that for the technology to begin to realise its potential, there needs to be significantly greater focus on educating stakeholders, at all levels, on the commercial and regulatory imperatives for successful DG uptake.

This commentary summarises the detailed analysis undertaken by CAE. The sections that follow look at the role of DG within the New Zealand electricity market and the likely technologies and fuel sources for DG in New Zealand. Based on the specific factors influencing DG in New Zealand, penetration scenarios are developed for DG investment.

Given the current environment of electricity shortfalls and increasing dependence on imported fuels, the penetration and uptake of DG is a very important question in the context of security of New Zealand's energy supply.

A DEFINITION OF DG

A useful definition of DG must be consistent with international practice and separate DG from traditional utility response to the energy supply and demand equations. For this reason, CAE has developed a technical definition that is sufficiently wide to take account of the range of opportunities that DG offers. DG is "niche electricity supply for local needs: small-scale, local to the point of use, either embedded in the distribution network or a stand-alone supply (the supply-side option), and assisted by the advancement of energy management measures (the demand-side option)".

There are many possible configurations for the application of DG:

- co-generation plant at industrial or commercial sites
- stand-by generation using diesel, gas, coal, geothermal and other fuel sources
- generation plant supplying directly into local distribution networks, such as wind farms
- micro-grid (islanded) operation
- electricity storage devices to meet demand peaks
- fuel switching at times of system peaks
- demand-side management systems.

DG is not technology or fuel dependent but instead is differentiated by modularity, distributed resources and scale. These characteristics are discussed in the sections that follow.

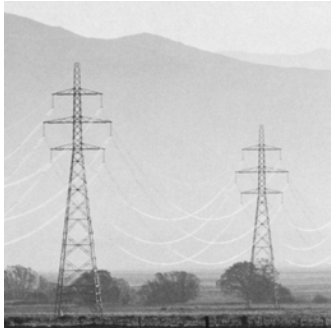
HISTORICAL BACKGROUND TO ELECTRICITY GENERATION IN NEW ZEALAND

The New Zealand electricity industry has its origins in distributed generation, later replaced by a state-owned, centrally planned institutional structure based essentially on the benefits of economies of scale and regional distribution. Electricity generation and transmission became a function of central government, carried out on a national basis as a single entity by a government department. Distribution was carried out by municipalities or regionally focused electricity supply authorities having exclusive rights to sell electricity within their franchise areas. Planning of generation and transmission capacity expansion was integrated and implemented on a long-term basis by central government.

After the Second World War, the principal focus of capacity expansion was large hydro and later thermal power stations with an integrated, centrally controlled national transmission grid, including the Cook Strait DC interconnection. Although investment in local area distribution was controlled by the authorities themselves, the bulk supply tariff was set each year by central government.

This structure reflected the growth of infrastructure to meet the requirements of the nation. The flow of electricity was uni-directional, from generator to grid to distributor and to consumer. The industry was closely regulated. Consumers had no option but to purchase from the local electricity supply authority, except in the case of the 12 largest industrial consumers, which purchased directly from the New Zealand Electricity Department.

Wholesale prices generally reflected the expected long run marginal cost of generation, and retail prices were structured so that all consumers within each supply area paid similar prices irrespective of location. Household prices were 'cross-subsidised' by commercial and industrial prices and the industry was committed to supplying electricity to virtually all inhabited parts of the country through the national and local grids.



ELECTRICITY INDUSTRY REFORM

Although the centrally planned supply network generally met consumer demand for electricity, there was considerable debate over its economic efficiency and the absence of competitive elements. These concerns were heightened in the 1970s when the first oil price shock disconnected demand for electricity from traditional growth patterns with a resulting overhang in generation capacity, subsequently exacerbated by a huge cost overrun on the Clyde Dam project.

The reforming governments of the 1980s and 1990s set about to improve the efficiency of the industry and to introduce competition and choice for consumers. This restructuring of the industry occurred in a number of stages and has evolved as the industry adapted to a more competitive environment.

Main electricity market restructurings, 1988 - 2003

In recognition of its monopoly position, the national transmission assets were separated from the national generation entity in 1988 and operated as Transpower, a profit-making state-owned corporation.

In 1992, the central generating assets were split into four competing generation companies, three of which remain owned by the state and one a public listed company. Electricity supply is now from as many as 16 generating companies, of which the SOEs Meridian Energy (33% of supply), Mighty River Power (10%) and Genesis Power (14%) and listed company Contact Energy (22%) are the largest.

A wholesale market company was established in 1993, providing a price-setting wholesale electricity pool and hedge contracts. About three-quarters of electricity is exchanged through the wholesale pool, and the remainder by term contracts established directly between generators and retailers and large consumers.

Local electricity supply authorities have been privatised and exclusive franchise areas abolished, permitting competition between retail companies for commercial and industrial consumers. From 1993, the number of retail companies subsequently fell from 50 or more, to less than ten.

Because of concern that genuine competition was not occurring at the retail level, these companies were then forced to split their activities into distribution lines services and energy supply. The electricity sector now consists of five major energy retail supply companies competing in various regions of the country, and 30 lines companies some of which have grouped forming 24 essentially separate network operations. Some of these companies are involved in analogous natural gas supply, and most energy supply retailers are vertically integrated with the electricity generation companies.

A system of light-handed regulation has been promulgated, utilising information disclosure to facilitate price negotiation, backed up by the general provisions of the Commerce Act to prevent market dominance. The disclosure requirements for the monopoly lines businesses are more rigorous, and new procedures for establishing transmission prices are in the process of being implemented. Cross-subsidy of residential prices have been removed and consumers effectively are expected to pay the cost of supply, notably in remote locations where the obligation to supply will also cease in 2013.

An initial prohibition on network companies being allowed to generate has been relaxed so that now there is no limit for generation from new renewables and a limit of 5 MW for other generating capacity.

The changes in the market structure have been reflected in new patterns of investment and activity by different industry stakeholders. Investment in major new generating plant, such as the Taranaki Combined Cycle power station, was not made by the traditional central generator but by a consortium of electricity purchasers, private generators and technology providers. Smaller generating plant has also been constructed on industrial sites such as the Te Awamutu dairy factory, providing electricity and heat energy for the site and exporting surplus electricity back into the grid. Export is contracted through complex arrangements between consumer, energy retailer, fuel supplier and network company. The flow of electricity is no longer uni-directional and electricity consumers can be suppliers to the grid when economics and their own electricity needs permit.

Electricity pricing is now more responsive to supply and demand on a short-term basis because of the operation of the wholesale market, setting prices on a half-hourly basis which more closely reflect the true marginal cost of supply. Location and fixed costs are increasingly being reflected in the structure of electricity pricing through the inclusion of nodal pricing in Transpower's pricing structure, and fixed costs are commonly an explicit element of retail prices. Electricity retailers are increasingly providing more purchase options to consumers in terms of pricing structure, reliability and quality of supply, particularly to larger electricity users.

The changes that have occurred in the New Zealand electricity industry over the last decade have gone beyond normal evolution. The question is whether this change has had a desirable outcome and placed the industry on a secure new footing for the future, particularly for delivering new generation capacity. The New Zealand energy market is small with relatively few participants. The linear nature of the transmission network and New Zealand patterns of energy use are special features of the sector, which are not replicated internationally.

distributed generation in the new zealand context

THE CONCEPT OF DG

DG is not about the introduction of new technology, but instead a concept of opportunity in the electricity supply system. DG can provide energy supply, or strengthen networks, both of which may be local requirements despite the local area being connected to the national grid. The importance of local generation can often arise because of national network constraints. DG is very specific and it is the relationships between the parties that are more likely to determine whether an electricity generation facility is DG, rather than the technology type or size of the facility.

The technology characteristics that are most necessary for DG can be quite different from those necessary for wholesale market electricity. A major misconception held by many is that all renewable electricity generation is DG, and that DG will be the panacea to fix current market problems. Neither is the case. The misconception is apparent, for example, in the United Kingdom where the DG policies being developed by the Government are really only a policy to increase the use of renewables. Although this is an important goal, this limited view can have the counter-effect of moving focus away from more immediately effective DG options.

A particular case in point is that of wind generation. Current wind farms are not true DG as they principally supply electricity into the national grid. To be DG they need to be controllable for local benefits, most of which wind energy cannot provide because of its variable output. However, if wind energy is linked with hydro or a diesel engine, for example, so that it can provide reliable system voltage security, or local embedding so as to defer network strengthening, then wind energy starts becoming DG. Linking wind and small-scale hydro together in a pump storage scheme means that a contract for guaranteed supply can be entered into. This increases the value of both the hydro and wind energy components of the overall DG scheme.

The wholesale electricity market is about capacity and is managed to meet power requirements at point of supply. DG plant is often installed to provide stand-by or back-up electricity supply when reliability is important, such as for industrial plant. When the energy flow is constrained in any way, as it is in many places in New Zealand, then DG can fill the supply need quickly and effectively. The choice of technology to meet this need will depend on fuel availability, cost and other factors. Of course in some instances investment in network augmentation is a more efficient investment.

Proven DG systems span a wide range of technologies, capacities, and energy sources and have been utilised for a number of years. The view of DG is often clouded by the lobbying of protagonists for particular renewable energy forms without consideration at the national level of the technical uncertainty associated with immature or emerging technologies.

In the current early phase of DG penetration, there is thus a need to distinguish:

- the technological pathways that offer the most opportunity for increased penetration of alternative energy sources, while also enhancing the reliability of electricity supplies in the near term
- new concepts, strategies and techniques that need to be developed and implemented in order to improve the production and distribution of electricity and other energy forms.

DG USE IN NEW ZEALAND

DG was the initial form of electricity supply in New Zealand, with electricity generated and supplied for local consumption using either hydro or steam turbines. As more users of electricity connected to local electricity systems, the economies of scale of constructing large hydro stations prevailed and DG became more relegated to niche utilisation. DG has remained in the form of steam turbines or small hydro plants, in isolated areas such as the West Coast of the South Island. In these areas, the small local plant has supplied electricity until eventually each community was connected to the local distribution network.

The second wave of DG in New Zealand came with industrial co-generation plant and the government support for the construction of small (around 30 MWe) hydro schemes that some power boards and municipal electricity departments were encouraged to build during the 1950s and later.

The local steam turbine has now given way to the diesel generator and even today there are communities throughout New Zealand, such as Milford Sound, that are still dependent on local diesel electricity generation. Milford Sound also has its small hydro plant and is a good example of hydro and diesel together providing an integrated supply solution that can meet a fluctuating electricity demand with reasonable reliability.

Investment in industrial co-generation facilities was the third wave of DG in New Zealand. These projects typically involved large-scale investments, mostly gas-fired, and still contribute to a significant share of the potential DG market. Up until then, co-generation had been largely fuelled by diesel, landfill gas and some natural gas. This is now giving way to the next wave of DG that is likely to be led by investment in a small niche plant and an evolving renewables sector supported by Government policy.

The increased flexibility from the disaggregation and restructuring of the electricity industry provides a more fertile environment for the adoption of DG than the previous centrally orientated uni-directional structure. Investment decisions are more likely to be made on a commercial basis. Pricing mechanisms make the true costs of generation more transparent and greater flexibility is afforded to potential participants to enter the market. With government no longer underwriting the risk implicit in large generation and transmission projects, the smaller scale of DG projects has attractions for investors in the relatively immature New Zealand electricity market.

Examples of DG have been established while others have failed because of economics or of contractual or pricing considerations. However, for a range of reasons outlined below, it is now opportune for DG to take a seat amongst the options that consumers consider when addressing future electricity supply requirements.

DG AND PRIMARY ENERGY SUPPLY

New Zealand's primary energy supply is roughly 760 PJ per year with consumer energy demand around 460 PJ. Electricity contributes only 120 PJ or 27% of consumer energy requirements and is thus only one of several competing energy forms. Although it has a natural technical monopoly in some applications, electricity must compete with gas, LPG, coal and oil products in many industrial, commercial and household applications, both at grid-connected and isolated sites. This is particularly the case where fuel is used directly for heating and industrial processes.

From an energy standpoint, DG must therefore be competitive with other energy forms available at the point of generation, as well as being technically the best means by which to supply electricity. A complete analysis of DG options should take into account all energy supply options, particularly those at sites with multiple energy applications or requirements.

Competing forms of energy for direct use, such as coal and gas, are not only potential competitors to DG but also are an implicit part of DG projects using thermal generation technology. Natural gas is the principal contender as the thermal fuel of choice for DG because of its utility in gas turbines and reciprocating engines. Its future price and availability at potential generation sites will be a strong influence on the competitiveness of DG relative to grid-sourced electricity, which in turn is influenced by the gas prices available to the large generating companies. The price of natural gas to the generating companies and to potential distributed generators stands as a principal sensitivity in the assessment of DG projects, particularly with price rises imminent as a result of the reduction of Maui gas availability and the uncertainty surrounding development of the Pohokura and Kupe offshore gas fields.

For most of the last 30 years, energy thinking has centred on large-scale electricity supply despite its relatively small contribution to primary energy supply. Combined with the availability of large quantities of gas from the Maui field, this has offered little incentive to look for anything other than an electricity solution in meeting future energy needs. This situation is changing quickly and DG is important in offering an alternative price path for energy users.

THE ROLE OF DG

The New Zealand electricity market is characterised by few significant load centres and a widely dispersed, lightly loaded, rural network. One percent of all New Zealand electricity customers account for 70% of the total industrial and commercial electricity consumption. Fewer than 150 users have loads within the 1- 5 MW scale, typical of conventional distributed generation modes, and New Zealand is likely to embrace systems of less than 1 MW capacity – quite different from many other developed countries. At this scale, distributed generation is likely to be less technically feasible than alternative energy efficiency options, and questions of system adequacy are likely to be more important than reduced energy consumption.

The needs that drive DG opportunities and the circumstances in which they occur can vary considerably and in many cases will involve the activities of a range of parties, including retailers, electricity suppliers/ lines companies and consumers. Investment can be made by any or all of these parties. In general, there are three principal objectives of DG investment.

Extending energy supply

Demand for electricity can be met by installing local generation capacity. There are many configurations for this type of application, for example:

- Generation plant installed at industrial or commercial sites to meet or reduce electricity purchases, such as co-generation plant and stand-by electricity generation capacity. The configuration of the larger sites, particularly co-generation, tends to be very site-specific, with economics heavily influenced by the total energy requirements of the plant and the availability and price of fuel to fire the generation and heat-raising plant. Fuels typically used in these applications include natural gas and coal.
- Embedded generation plant supplying electricity directly into the local distribution network. Examples include electricity generated from small renewable energy plants such as landfill gas.
- Generating plant to supply one or more customers though an islanded microgrid, isolated from the main grid.

Complementing lines capacity

Establishing a source of electricity generation close to the point of electricity consumption defers or obviates the need to expand the capacity of transmission or distribution lines to meet increasing demand. Types of technologies used for this application include:

- Generation at industrial and commercial sites, as noted above, with the potential for any surplus electricity to be sold back to the electricity supplier when economics permit, thereby reducing the load in the adjacent transmission network.

- Portable or temporary sources of generation to reduce seasonal or short-term peaks.
- Generation at remote locations to eliminate the need to install distribution lines.
- Electricity storage devices to meet demand peaks.
- Fuel switching, e.g. load transferred from electricity to gas at times of system peak, or demand-side measures and energy efficiency measures.

Hedging electricity prices

The installation of DG provides a cap on prices, within the capacity of a facility, as a risk management strategy against increasing price. In these instances, the more efficient use of the capital asset base is also a driver.

There can be additional incentives for consumers to install DG facilities. Paramount amongst these is security of electricity supply, especially for hospitals and some industrial processing plants where stand-by generation capacity is commonplace. This generation capacity can also be used for peak shaving to reduce required lines capacity or to send surplus generation back to the grid when economics dictate. The need for enhanced quality of electricity supply is also growing in demand, particularly from organisations using computer and Internet facilities, and can be provided by DG.

MARKET DYNAMICS AND DG

The co-operation of electricity suppliers and consumers is a common and often necessary feature in many DG projects. Although the objectives and interests of the two may be apparently different (for example the reduction of peak lines load versus the production of process heat in a co-generation project), the benefits are often synergistic and the boundaries between each party's activities can become indistinct, particularly with a combined heat and power (CHP) plant. Innovative solutions are often needed to realise such interdependent activities, in both the technical and contractual contexts, and the division between asset ownership and services provided can be structured to enhance the viability of projects. The variability in supplier and consumer needs and their combinations means that there is a wide range of possibilities for DG, particularly in larger industrial applications that become highly site-specific.

Likewise, interconnection between the distribution network and generator is an important element in the development of DG projects, particularly at sites where electricity is to be supplied to and from the site, depending on whether there is a surplus or deficit of electricity self-generation at the site. Satisfactory interconnection arrangements are not limited to technical and metering requirements but must include contractual and pricing arrangements that encourage interconnection. These are not always straightforward, as it is not necessarily in the interests of electricity supply companies to encourage DG, especially if the site is located in the wrong place and does nothing to enhance system performance.

There are regulatory and policy issues as well as technological barriers. These barriers can become opportunities when they include government intervention to encourage co-operation to increase system benefits. Examples include providing market opportunities to enable full price recognition for the locational value of DG investment, and offering new mechanisms for realising the environmental benefits that arise from many DG investments.

New Zealand is further down the DG pathway than is generally recognised. With added experience, the technical and regulatory issues that are currently acting to impede DG uptake will be better understood and thus lead the way for increasing investment. With increased experience, it is also realistic to envisage a heightened awareness and migration towards increasing use of DG, using enabling technologies such as net metering and electricity-quality management systems that will herald significant changes in supply structures.

However, it must be recognised that DG competes with the conventional alternatives of centralised generation and lines capacity expansion based on cost and strategic needs. DG must also compete with a range of demand-side options that will reduce demand for electricity and/or reduce peak capacity requirements in transmission and distribution lines. These options include increased efficiency in the utilisation of electricity, substitution of electricity by other energy forms, and demand-side management or control through electricity pricing incentives to flatten distribution load curves. All these options are already successfully applied in New Zealand.

ENVIRONMENTAL AND SOCIAL IMPLICATIONS OF DG

Although environmental and social aspects have not been strong drivers for DG in New Zealand, they are strong beneficiaries of DG.

DG provides local solutions to local energy needs and the benefits—economic, social and environmental—are directly transferable to local communities. Where DG is developed and implemented in conjunction with communities, the benefits are maximised to both the community and the DG owner. Quality consultation with the local community can identify mutual benefits at an early stage and result in both parties working together to identify issues and optimum solutions.

However, the environmental and social benefits of DG are often not recognised early, if at all, with the result that the obtaining of resource consents in particular can be unnecessarily delayed or even stopped. This has a serious impact for the potential DG investor and adds to overall costs.

In New Zealand, DG will be most useful in providing a more diverse energy base for electricity generation and indirectly provide an opportunity to better manage present hydro storage. DG is also a means of utilising generation from renewable energy sources such as hydro and wind in situations that would otherwise not be economic if supplied into the central grid. In some instances, savings in transmission and distribution costs, and the concurrent reduction in network losses, have the potential to make these applications cost competitive, particularly in more remote, dispersed distribution networks. These benefits will be augmented by the reduction of CO_2 emissions through renewable generation displacing grid-derived thermal generation. CO_2 reductions may also be attained from thermal DG, particularly where municipal or timber process waste is used as a fuel and significant electricity losses can be avoided. However, such situations require close scrutiny to determine the net impact on emissions to account for the different efficiencies of thermal equipment used and the different emissions of the fuels.

It is anticipated that the investment environment of the future will involve the impact of a carbon charge post-2007 or Negotiated Greenhouse Agreements (NGAs) for certain major industries, and other regulatory measures aimed at greenhouse gas (GHG) reduction. This will be a major influencing factor on the uptake of the various types and forms of DG. Imposition of a carbon tax is likely to benefit almost all DG opportunities, including the use of diesels, because integration within the total system results in a CO_2 emission benefit relative to new fossil generation from large conventional coal plant. Climate change issues simply make DG opportunities more valuable and do not change the raft of opportunities available because they already have a neutral or positive greenhouse gas footprint.

If the electricity policy and regulatory framework is appropriately aligned with policies that promote reduction in greenhouse gas emissions and harnessing renewable energy, DG can make a real and viable social, economic and environmental contribution to New Zealand's primary energy supply.

conversion technologies for distributed generation

One of the reasons that DG is attracting new interest is because of the advances made in the efficiencies and costs of long-standing technology such as microturbines, stirling engines, wind turbines, solar photovoltaics (PV) and the promise of improved fuel efficiency from evolving technologies such as fuel cells. Table 1 shows the electrical efficiency range, co-generation efficiency range, size range and predominant fuel types for various DG technologies.

The reality is that most DG to date has been developed by using commonly used technology such as reciprocating engines, combustion turbines and small hydro, and that the developing technologies have yet to approach mature market costs. In all probability, DG in New Zealand up to 2015 will use this existing technology and some additional wind power. Developments beyond then will be driven as much by the industry structure of the day and its modus operandi as by the technologies available.

TABLE 1: DG TECHNOLOGIES

	ELECTRICAL EFFICIENCY (%)	COGENERATION EFFICIENCY (%)	SIZE RANGE	FUEL
Gas turbine	28 - 40	80 - 97	500 kWe - 300 MWe	Natural gas, liquid fuels
Steam turbine	25 - 35	80 - 90	Extensive	Natural gas, liquid and solid fuels
Reciprocating engines	25 - 40	50 - 70	1 kWe - 15 MWe+	Combustible gas, gasoline, diesel
Microturbine	25 - 30	50 - 80	25 - 500 kWe	Natural gas, diesel, propane
Stirling engine	12 - 20	50 - 70	1 - 25 kWe	Natural gas and some liquid fuels
Fuel cell	30 - 55	70 - 96	1 kWe - 10 MWe	Natural gas, fuel oil, hydrogen
Biomass systems	17	60 - 80	Extensive	Biomass - gases, liquids and solids
Photovoltaics	6 - 19	N/A	1 - 100 kWe	Sunlight
Small hydro	N/A	N/A	<10 MWe	Water head
On-site wind	N/A	N/A	5 kWe - 5 MWe	Wind

CONVENTIONAL GENERATION TECHNOLOGIES

Conventional technologies such as diesel generators currently being deployed within local networks will remain the technologies of choice for DG for the foreseeable future. They have inherent flexibility and reliability that are essential to DG applications. These stand-alone facilities can also be easily relocated, providing good interim solutions as new technologies or longer-term solutions are implemented. However, it needs to be recognised that plant utilisation factors are generally low compared to main wholesale market generating capacity plant.

Reciprocating engines

Also known as internal combustion engines, (either spark ignition or compression ignition diesel types), reciprocating engines are available in sizes from 1 kWe to 15 MWe. Co-generation capability also exists since most of the input energy leaves as heat in the exhaust gas and the cooling water, and can be recovered.

Reciprocating engines are also widely used for back-up supply and mobile generation, typically generating electricity, but not recovering waste heat thereby necessitating fan-blown radiators. The technology is fully mature and is the usual technology of choice for stand-by power. Until the advent of microturbines, it had no competition.

Co-generation

Co-generation, also known as combined heat and power (CHP), is the simultaneous production of electricity, heat and/or cooling at or near the point of consumption. CHP applications are chiefly confined to industrial customers, where the primary need is to supply a heat load. The economics of such CHP projects is largely predicated on the customer having a waste by-product to use as fuel, thus avoiding a need for disposal at an added cost, or being closely located to such a source of material. The industrial CHP market in New Zealand is well served and is now basically confined to new site operations.

There is still potential to develop more CHP in the commercial sector, but there has been no penetration in the domestic sector.

Gas turbines

Gas turbines have been in use for over 40 years in the electricity generation market. Liquid or gaseous fuels are combusted within the turbine, creating an expansion of gases. As these gases expand and leave the turbine, they exit through a system of blades that absorb some of the energy and convert it into mechanical energy to rotate the generator.

Gas turbines typically convert 20 - 45% of the input energy into electrical energy. The gas turbine exhaust can be used to produce steam that drives a condensing steam turbine which combined can achieve up to 58% fuel to electric efficiency. By locating the plant near thermal users, switching to a back-pressure steam turbine and using exhaust heat directly in an industrial process, combined cycle gas turbine CHP plants achieve efficiencies of 85– 97%.

Gas turbines were used for electricity generation from after the Second World War. Their appeal was that they were cheap to build and were ideal for emergency and peak-load stand-by use because of their rapid starting and loading capabilities. They can make a significant contribution even if used infrequently in a DG application. Despite these advantages, gas turbines have rarely been used in DG situations in New Zealand.

Steam turbines
Steam turbines are an even more long-standing technology. When fuel is combusted, or hot exhaust gas is used in a boiler to produce steam at high pressures, that steam pressure can drive a turbine that in turn drives a generator. Almost any fuel can be used.

When the steam is simply condensed at the exit of the steam turbine, between 15% and 38% of the energy in the fuel or exhaust is converted to electricity. Condensing steam turbines are at the bottom of the efficiency scale among current technologies.

By contrast, a back-pressure steam turbine produces two products, heat and power. The turbine extracts some electricity from the steam, lowering both the pressure and temperature of the steam. The steam is then used to supply thermal energy to a process, or to heat and cool buildings, replacing boiler fuel. The efficiency is measured by the energy produced divided by the net change in fuel to meet the thermal load, and often exceeds 85%.

Until the introduction of diesel engines, steam turbines were the dominant technology for DG applications.

EMERGING GENERATION TECHNOLOGIES

A number of generation technologies are currently in the research phase. Some of these are expected to have a greater significance for DG applications after 2015. Others are becoming commercial because of advances in metallurgy, synthetic materials, electronics and other key contributory fields. There has recently been a surge in commercial interest to provide small-scale electric generating plant of one form or another. The markets for these technologies lie not only as DG in existing networks but also in situations where electrical services are not yet widely available, if at all.

Although there may be niche opportunities for these emerging technologies, their penetration and contribution towards meeting New Zealand's energy needs before 2015 will be limited at best. The technological risk, scalability, and the technical barriers to network connection make these technologies unrealistic large-scale options in the near term.

Stirling engines
Stirling engines are external combustion systems in which the fuel does not enter the working cylinders. Instead, it is combusted outside of a cylinder to warm an inert gas, which is sealed within the cylinders. It is this inert gas, typically nitrogen or helium, which does the actual work on the pistons. Stirling engines are currently capable of electrical efficiencies of 12-25% in the 1-25 kWe range and commercial models are now becoming available.

Stirling engines operate on temperature differences of many hundreds of degrees and so require a high temperature source, either from fuel combustion or from a heat source such as concentrated direct sunlight, and a cold sink usually provided by water-cooling. As with the case of internal combustion engines, this heated water can be put to use to provide CHP. Stirling engines, like microturbines, are inherently quieter than internal combustion engines but are technologically less mature. Stirling engines are also being developed on a scale smaller than microturbines, and are focused more on the domestic CHP market (AC generation) and remote area electricity supplies (DC generation).

Fuel cells
Fuel cells, ranging in size from 1 kWe to 10 MWe, are electrochemical energy conversion devices that use hydrogen and oxygen to produce electricity, heat and water. It is a relatively new technology and capital costs remain very high. Significant commercial and technical development will be required before fuel cells can be expected to be suitable for a general market. At the end of 2001, there was a world-wide total of only 45 MWe of fuel cell capacity with 1 GWe projected for 2006.

Electrical production is more efficient (40 - 60%) when hydrogen is used rather than other fuels. Where hydrogen is not supplied directly, it is necessary to use a hydrocarbon fuel reformer. Fuel cells produce direct current and therefore also require inverters to enable the output to be synchronised with the grid. Overall efficiencies offer no advantage over other technology routes.

The future potential for fuel cells as on-site DG power plants is dependent on significant cost reductions and technological advance. The molten carbonate technology and the solid oxide technology both have exhaust heat suitable for combined cycle plants and CHP. The current technology has nearly zero emissions of NOx but, despite the high investment, only achieve efficiencies comparable with the largest combined cycle gas turbine (CCGT) plant.

Microturbines
Microturbines are smaller versions of gas turbines. Typically in the 25-500 kWe range, they are capable of electrical efficiencies of 20 - 30% with the clear potential for use in co-generation. These systems are now becoming commercially available although there remains scope for cost reduction and efficiency improvement.

In a DG situation, the microturbine is ideal for use in a standard package with identical units installed in parallel as the load requires. Microturbines are quieter in operation than equivalent-sized combustion engines. Manufacturers now offer package units that can be paralleled for greater capacity requirements, with or without heat recuperation, with load following or export control of the generator.

RENEWABLE ENERGY GENERATION TECHNOLOGIES

Renewable energy technologies are driven principally by climate change mitigation and community moves to adoption of sustainable energy sources. Renewable energy sources bring with them a number of issues such as lack of controllability, as in the case of wind and solar power, and reliability of river inflows in the case of hydro. Research into storage technologies, such as with phase-change materials, will eventually allow a greater penetration of renewable energy as DG.

To obtain the supply characteristics from renewables that are necessary for DG, as are provided by conventional technologies, requires adaptation of existing supply arrangements, the involvement of new players, and further technical complexity.

Individual renewable energy sources are discussed in the section on fuel characteristics and availability.

enabling technologies for distributed generation

THE IMPORTANCE OF ENABLING TECHNOLOGIES

In order for DG and demand-side management (DSM) to be effective, it will be necessary to employ the technologies of the information age. The focus of DG uptake is not about the technologies of conversion such as fuel cells, wind turbines, and microturbines, but about the enabling technologies of two-way communication to every customer and plant item on the network: real-time pricing and smart metering, and high-level modelling of the system.

A 'plug and play' approach using modular equipment appears to have the greatest potential in the domestic DG market, where product standardisation and mass production can deliver economic solutions. This will not happen while the low-voltage distribution networks remain in their present state, that is, with no technical changes to accommodate DG systems, or with the antiquated meters remaining in use.

As most network businesses have the majority of their asset base (and revenue) tied up in lower-voltage networks, there will be a resistance to change without a corresponding revenue compensation. While the numbers of domestic retailers remain small in relation to load customers, there is little push for change. As a result, these issues are seen by network companies as very long term, with most companies just tracking the market. However, for this market to expand, it seems inevitable that additional network control systems will need to be introduced to ensure that the existing infrastructure can cope as the numbers of domestic DG installations increase.

The telecommunications industry and the expansion of the Internet can serve to give strong leads and opportunities for more comprehensive communications and control infrastructure to sit alongside the electrical network infrastructure, although the actual means of communication should be separate from the protocols used. A standard protocol should be flexible enough to use whatever resource is available, be it power line carrier, PSTN, cable TV, or mobile phone text messages. Of course, the communications system does not need to be dedicated to DG, or even just to energy.

ENABLING TECHNOLOGIES

Communications and smart metering

There have been many structural changes made to the electricity supply and delivery system in the last decade and it is now opportune to address the modernisation of the physical aspects of both systems to capture the potential of the deregulation process and to bring supply security to the fore. The advent of mass-produced DG technology makes modernisation of metering, load management and communications a vital issue. Without these facilities, neither DG nor automated management of load on a wide scale will be fully achievable.

For DG and DSM deployment to be readily supported and encouraged, an information system is desirable that has many of the following capabilities:

- management of DG and DSM according to system capacity and service requirements
- remote meter reading, including time-frame of use (TOU) and debit and credit metering
- remote disconnection for credit control, customer switching, pre-payment and so on.
- ICP switching and registry
- losses measurement and reconciliation
- outage mapping under storm conditions
- load surveying of networks and customers
- distribution network automation services
- complex billing managing multiple services, real-time pricing and providing XML-based files and customer relationship management.

The required combination of communication technologies, primarily dedicated to electricity, will have the ability to offer auxiliary service features to increase revenue such as load cycling, demand-side reserves margin, gas and water billing, loss measurement, security monitoring, network demand and energy TOU for individual customers or groups.

Energy system modelling

An area of particular interest in ensuring better use of existing assets and future decision-making is the field of energy system modelling. 'First principle' arguments are no longer an appropriate way of driving system decisions, whether they are decisions related to public policy development or to private facilities planning. The system interactions are simply too complex to yield to intuition, particularly when the dynamics of storage use, demand shift, and variable supply are considered. Instead, there needs to be high-resolution modelling.

Moreover, unit efficiency should not be a goal in itself. Aggregate greenhouse gas reduction and/or decreased resource depletion should be the primary drivers. High-resolution modelling can factor in these and related goals as part of the primary problem definition.

One example is a dynamic energy, emissions and cost optimisation model (DEECO), currently being developed at Berlin University. This is a generic energy system-modelling environment that can be used to evaluate proposed changes in operational policy and/or system structure. The resultant monetary costs can be interpreted directly or traded off against non-monetary criteria, such as reduced CO_2.

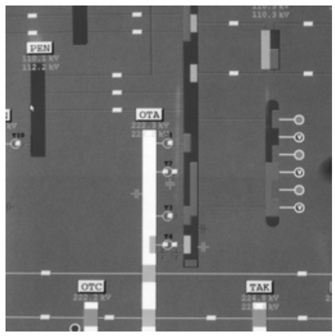
Signalling

The principal aspect of DG for obtaining wider network benefits is the ability of one party to signal the DG generator that the DG plant should be turned on or off. These signals can be received and acted on using contracts between the parties. For example, with ripple control, the customer gives the discretion to the network generator within limits set by

supply contract. A signal to another DG owner, say a hospital, may leave the discretion to generate to the DG owner.
When the signals are accompanied by price information, the power of the arrangements is enhanced.

Real-time monitoring
For DG to be most effective, decision-makers need to have access to real-time information on electricity supply and demand. Network operators have this information down to the level of substation equipment and in some cases to large industrial consumers. To most effectively obtain the full benefits of DG and demand management, the communication of real-time information needs to be put in the hands of customers.

The technology for real-time monitoring is readily available at appropriate cost. What is lacking is the interest from customers in installing it. One of the major benefits of high spot prices is that more electricity consumers are likely to take an interest in their energy use if they have the information.



fuels for distributed generation

DESIRABLE CHARACTERISTICS OF FUELS FOR DG

The desirable characteristics of fuels for DG use are:

- resource availability at a quantity and annual production rate for the economic life of the DG facility
- long-term supply contracts with terms and conditions that are complementary to the electricity (and heat) wholesale market and with transmission and distribution commercial characteristics
- stable and predictable price that is competitive with competing fuels and generation technologies
- transportable to preferred DG locations on a flexible delivery profile, including (where appropriate) alternative delivery means and routes
- easily stored and retaining physical properties during storage and transportation
- available within a stable regulatory regime that is consistent with the wholesale electricity, transmission and distribution market regulatory regimes
- amenable to use in high-efficiency, low-capital and operating cost, and high availability and reliability electricity generation technology
- low capital investment requirements for emission controls and waste disposal by virtue of low levels of atmospheric and other emissions or waste by-products emitted during the production, transport, storage and combustion processes
- low environmental impact in respect of greenhouse gas environmental concerns and regulatory regimes associated with global warming issues, including carbon taxes and emissions trading.

TABLE 2: **INFLUENCES ON FUEL TYPE**

CASE STUDY	COMMERCIAL ISSUES	EXTERNALITY ISSUES	REGULATORY ISSUES	NEW ZEALAND SPECIAL FACTORS
Bioenergy	Availability/cost of fuel. Need for waste disposal. Use for heat on or off-site. Principally a heat source.	Air and noise emissions.	Solution for environmental problems. 40 MWth installed annually (for timber drying). Scale issue – too small for viable electricity generation.	Growing source of wood, log exports produce waste. Competition for fuel from garden centres. Unlikely to be investment in NZ in large integrated wood processing facilities.
Wind	Proximity to the network. Hydro system backup. Cumulative capacity constrained (20% of network load). Does not solve capacity constraint.	Area of outstanding natural beauty. Noise and visual impact. Site accessibility.	Shared benefits. Distributors can own unlimited capacity. Can connection into the network be made at no greater cost than to the national grid?	NZ is a small, long, narrow island, in roaring 40's, long coastline. Hydro system backup opportunity favours wind.
Hydro	Water priority for generation is secondary to its use for irrigation. Opuha irrigation was not bankable without generation. District water supply scheme is an area of potential – dam outlet & pipeline turbines, retrofit options.	Minimum flow in natural water courses. Wild river preservation. Paternalism – regional strategic growth vs parochialism.	Water allocation – no value placed on water. Long & difficult consenting process – expected that only 10% of potential could be realised for this reason. Excluded under current renewable definition. Conservation orders put resource off-limits.	Climate impacts generally. Irrigation needs. Cultural sensitivity to mixing waters. Water supply schemes match daily demand but not seasonal.
Fossil fuels	Fuel cost ability to respond to peak demand signal. Ability to parallel with the network Comparatively secure fuels.	Noise and air emissions. Co-firing with biofuel introduces renewable element.	Existing use provisions enable some type of generation. Local air quality plans are a potential spoiler. Gensets may be portable assets DG is an easy target.	Uncertain gas market dynamics. Substantial increase in gas price likely. Kyoto ratification. Large coal reserves.
Photovoltaics	High capital cost. Zero maintenance. Solid state	Life cycle costs in terms of emissions not quantified.	No regulatory barriers (no emissions). Buy-back and exit fee.	Winter peak demand – cloudy summers.
New technologies	Fuel cells, microturbines, Stirling engines. Capital costs. Heat load required. Limited fuel flexibility. High capacity factor.	Significant uptake may raise issues depending on fuel type.	Emissions depending on fuel type. In domestic situation CO_2 emissions not counted. Buy-back and exit fee.	Buildings generally not centrally heated.
Rural region/community/dwelling	Cost of connection to the network. Rural supply reliability.	Dependent on chosen technology.	2013 obligation to supply time horizon.	Decline in rural economies.

In practice, all of these favourable characteristics are unlikely to be present in one fuel, thus requiring commercial and technical trade-offs to be made during the development of a DG facility.

Until recently, the current optimum fuels for electricity generation in New Zealand have been hydro (zero fuel cost), natural gas (plentiful supply and efficient technology), and diesel (low installed cost), but other fuels such as geothermal (low fuel cost) and wind power (zero fuel cost) have improved in commercial and environmental attractiveness. In the current climate of declining gas reserves, coal is becoming more attractive in certain locations but suffers in context of greenhouse gas emissions and carbon tax issues. Fuels with potential niche application are liquefied petroleum gas, low-sulphur heavy fuel oil and distillates. A summary outline of current fuel use for electricity generation is given in Table 3.

The variability of all renewable sources of energy in New Zealand, apart from geothermal, means that for some time yet New Zealand will probably be reliant on fossil fuels to meet peak demand. Even if wind farms are built, their contribution at peak times cannot be certain, and co-firing wood with coal has not been economically justified.

FUEL CHARACTERISTICS AND AVAILABILITY

In respect of DG, the CAE study examined in detail the various factors influencing the use of the different fuel types available in New Zealand. The various issues identified are summarised in Table 2.

Fossil fuels

The use of diesel stand-by plant is already an important component of DG in New Zealand and its use is likely to increase through application of enabling technologies. Substantial stand-by plant is already installed, and with a change in the way it is controlled and integrated with the electricity market, greater value can be obtained from these assets.

Diesel plant has a high fuel cost component that can be justified if operation is only at peak demand periods. The high cost can be off-set by the payments that network companies can make if controllability is guaranteed.

Diesel is perceived to be more environmentally friendly than coal. The efficiency of diesel engines is 35 - 40% compared to coal-fired steam plant at 25 - 30%. The air emission quality issue will improve over time as New Zealand's diesel production turns to low sulphur levels, which in turn will allow the use of catalytic converters to further improve air quality standards. The opportunity also exists to use biodiesel or biofuel blends in the future.

Wind

Wind energy currently provides approximately 150 GWh per year of electricity, or under 0.5% of New Zealand's electricity generated. Up to 13 general areas have been identified as suitable for potential wind farming. The calculated average energy production levels available from these sites totals 9370 GWh/y.

EECA has suggested that if economic and resource consent conditions were favourable, New Zealand's wind resource could provide approximately 23% (7900 GWh hours per year) of the country's present electricity. This must be regarded as at the upper end of what is possible. A more realistic estimate, based on required energy at grid exit points, suggests a potential maximum contribution from wind power of about 1000 MW, or about 4000 GWh/y.

The main barriers to further development of wind energy in New Zealand are economics, resource consent risks, and network connection costs arising from location and technical constraints.

The technology for wind power is now mature and the installed cost of capital is decreasing, although it is still high compared with conventional fossil fuel plant. Wind turbines for grid connection are on the point of being financially viable and it is expected that 160 MWe could be built before 2015, although little of this will be DG. Wind-generated electricity will become more attractive relative to generation from fossil fuel over the next five years, although there are practical issues to take into account including siting from an aesthetic perspective, proximity to the network, and how robust the network is at the connection point.

As an intermittent renewable energy resource, wind will fit best in a support portfolio because it requires system back-up. Wind is useful when it complements hydro storage to some extent: when wind is contributing, then less water is required to be released from storage and is held in reserve for when wind is not contributing. The DG opportunity is therefore limited to meeting the local demand of a defined network area not requiring full

TABLE 3: **SUMMARY OF GENERATION BY FUEL TYPE**

FUEL TYPE	PJ	% OF TOTAL GENERATION
Hydro	88.9	63.9
Gas	32.6	23.5
Geothermal	9.9	7.1
Coal	3.1	2.2
Oil	0	0
Others	4.6	3.3
Total	139.1	100

Source: Energy Data File 2002, Ministry of Economic Development back-up, and to improving the economics of grid support charges. Beyond 10% of local system capacity, those benefits will diminish. Large-scale wind farms can compete at a higher level of penetration (potentially 20-30% of grid capacity) along with other forms of grid-connected generation, principally for supply to the wholesale electricity market, but still at the cost of requiring system back-up.

Most of the wind farms being contemplated in New Zealand are not predicated upon DG opportunities. Therefore, from the perspective of DG, wind farms offer the opportunity, but the opportunity is not there now. It will only exist if other DG opportunities are taken up as part of a portfolio. Similar remarks can be made about small-scale hydro schemes, although hydro fares slightly better as there is usually some storage compared with none for wind.

Small-scale hydro

Run-of-the-river or impounded water behind storage dams or coastal barrages are the usual energy source for hydro-electric plant. Impounding water sacrifices land area, and this issue alone now greatly limits proposals for new hydro unless strong support comes from the community affected, usually only where there is an over-riding interest in dual use of the water reservoir. Hydro was the initial technology of choice for electricity production in New Zealand and was installed for DG applications. Because of its high capital cost and the high cost associated with resource consenting, it has become less favoured.

Small-scale hydro potential in New Zealand is estimated at about 1000 MW but making allowance for drought-prone areas reduces this quantity to around 350 MW total capacity.

Hydro can be expected to gain a higher and more positive profile under DG as the local benefits can be associated with the local effects through transformation of the use of the land. Smaller hydro schemes associated with DG will gain recognition when storage of water on land is considered a valid land use alongside farming. Any hydro developments investigated during the period to 2015 are expected to be related to DG or will be part of a multi-use scheme, such as irrigation or a community water supply.

Use of hydro in DG applications will become more common, although the high costs of investigation and extremely high capital costs will be the principal barriers. In the past, economies of scale for construction drove the industry towards wholesale market generation and that will remain the case until energy costs increase significantly.

Geothermal

New Zealand has extensive expert knowledge of the extraction of underground geothermal heat and the transmission of steam for electricity generation. Historically this has been confined to large-scale electricity production.

Geothermal energy could make a significant additional contribution to New Zealand's generating capacity, but perceived environmental issues limit the potential. Using only current technology, and ignoring environmental and regulatory constraints, the high-temperature resource capacity is estimated to be about 3600 MW of electrical equivalent or about 75% of New Zealand's current total system demand. Only about 10% of this potential has been developed. Taking environmental and regulatory constraints into account reduces the potential to 898 MWe. Because of the inability to transport geothermal steam over more than a few tens of kilometres, these opportunities are essentially limited to large-scale centralised power generation, although some areas of the North Island lend themselves to geothermal energy for CHP projects. DG opportunities are essentially limited to complex binary plant.

Biogas

This resource is also geographically restricted. There are a number of landfill sites used for generation, but the opportunities are quite limited and are likely to be more so in the future as more advanced solutions to waste disposal are introduced, and greater levels of recycling are employed.

The disposal of waste from industry and farming will, however, be a major driver towards increased waste processing to produce biogas. This will have potential for DG applications and could start to become quite large by 2015.

Bioenergy

Biomass is regarded as a renewable fuel and has potential for use in DG co-generation systems. For electricity generation, the potential energy stored in biomass is typically extracted in one of the following ways:

- direct combustion of the biomass within a boiler, which can produce steam to drive a steam turbine
- converting the biomass through a gasifier or pyrolyser into either a liquid fuel or a combustible gas. This gas can then be used as a secondary fuel, e.g. for a gas turbine or CCGT
- liquid biofuel, e.g. biodiesel, can replace the equivalent fossil fuel type.

Currently, the generation of electricity from biomass is generally not financially viable unless the source of wood waste for fuel has a negative value, that is, if there is a cost of disposal. Only one significant bioenergy co-generation facility has been built in New Zealand in the recent past (the Kinleith pulp and paper mill), and even then the co-generation plant was installed only because of environmental performance issues with existing combustion plant and the otherwise substantial cost of wood processing waste disposal.

Bioenergy plant installed for heat production is common throughout New Zealand in the wood processing industry. Of the estimated 40 MWth of heat plant installed each year, the majority of this uses woody biomass as a fuel. It is expected, therefore, that any future bioenergy DG plant installed will build on the experiences from current heat plant investments and will be a co-generation process steam system embedded into the site. It is not expected that any such plant will be a significant net exporter of wholesale electricity. Under current forest management regimes, the delivered cost of the required additional waste streams for electricity export will act to constrain investment.

Solar energy

Direct conversion of sunlight into electricity using photovoltaic (PV) panels has been commercially available, at a price, for decades. Other forms of PV technology are emerging, but the high capital cost has largely confined their application to specialist needs such as low power requirements in locations remote from the grid.

Solar water heating is a distributed energy form that can have some of the characteristics of DG. It is local in application and can provide benefits to the electricity network similar to other DG forms. Solar hot water heating has a unique place in the renewables mix and can reduce total electricity demand. In many isolated areas of New Zealand the distribution network is reaching capacity or requires strengthening. Installation of solar water heating systems along with ripple control can reduce peak electricity demand and assist with load spreading. However, its effectiveness as a DG option is reduced by the fact that New Zealand does not have a summer energy problem.

New Zealand's solar insolation levels are relatively high for its latitude. PV panels therefore perform well, although from the viewpoint of large-scale use on networks, the capital cost will have to reduce dramatically. Using PV panels as a roofing surface on all types of building, once sufficient cost reduction had been achieved, would open up the market dramatically for DG systems. However, New Zealand has a peak winter demand with summer to winter energy prices at a ratio of 1:2 or greater, so the prognosis is for PV not to contribute to network-connected DG but to remain in a niche market for holiday homes and other remote power applications where the cost benefits are justifiable. While in energy terms this may not be a large contributor to DG, it is likely to be large in the number of applications.

the climate for DG investment in new zealand

MARKET DRIVERS FOR DG INVESTMENT

DG applications are highly localised niche arrangements commonly characterised by complex arrangements between investors, plant operators, electricity suppliers, transmission companies, network companies and consumers. These relationships are more complex than usually occur in wholesale market situations. The complexity for DG arises because of localised production, distribution and sale, each involving different parties.

The DG business opportunity is based around three imperatives:

- having an energy need
- having an energy source
- taking control of an energy risk management strategy.

The viability of investment in a project is dependent on internal rate of return on capital invested and on potential revenue streams. Beyond the business opportunity, the analysis of DG is typically based on one or a combination of the following factors:

- electricity availability and reliability
- quality of electricity supply
- need for grid reinforcement
- deferred network investment
- environmental benefits
- revenue earning
- asset utilisation
- carbon dioxide emissions
- social and environmental externalities
- local or regional economic benefits
- waste disposal.

Following are specific drivers that are creating heightened interest in DG in New Zealand.

Regulatory and commercial framework

Over the last 15 years, the energy regulatory and commercial framework has profoundly affected the way in which the electricity industry can structure and implement projects, permitting network companies and independents to development their own generation capacity to supply into distribution grids.

Electricity flow pattern changes

The pattern of electricity flow is changing, from uni-directional flow from centralised generators to grid to distributor and to consumer, to a flow network allowing the multi-directional flows that characterises some DG projects. Electricity consumers can be suppliers to the grid when economics and their own electricity needs permit, although this process can be impeded by conflicting interests within the industry.

Improved costs, efficiencies and reliabilities

Improved costs, efficiencies and reliabilities are making the generation of electricity more attractive, using small-scale and evolving technologies such as micro-turbines, photovoltaics, wind power and (in the longer term) fuels cells. Not all these technologies are generally commercially viable in New Zealand because of relatively low electricity prices and a relatively high level of security. However, because of its competitive structure, the New Zealand market is able to accept new technologies that can compete with traditional grid-supplied electricity.

Electricity consumption growth

New Zealand electricity consumption continues to grow at about 2% per annum. DG offers alternative electricity sources to supply this market and may reduce current transmission constraints (without the traditional expansion of the supply network) and increase generation capacity (without investment in large new plant). Choices between these routes to expansion are highly localised.

Resource availability

The continuing availability of resources such as new hydro and natural gas at competitive costs will be a significant factor in the development of DG. Constraints on the supply of these resources to the central generating companies, notably hydro reserves in recent years, has resulted in potential for DG to provide peak shaving and stand-by capacity in response to increasing volatility in electricity price.

Renewable resources

DG from renewable resources such as hydro and wind will become increasingly attractive as a value is placed on greenhouse gas (GHG) emissions and potential environmental costs. Similarly, some thermal DG may have advantages over larger grid-supplied thermal generation plants as small-scale efficiencies improve and overall system losses are reduced. Arguably, smaller-scale projects will become easier to leverage in the increasingly environmentally conscious consenting process.

Focus on consumer needs

An increasing focus by companies on consumer needs and meeting consumers' total energy requirements will reveal DG projects with common benefits and encourage projects to be developed jointly by suppliers and consumers. Electricity quality and reliability requirements of consumers will assume a greater profile.

Electricity spot market customer growth

The expansion of the numbers of customers who purchase electricity on the spot market is providing strong incentives for them to hedge prices. This can be done by contract or by investment by the customer in DG.

COMMERCIAL EXPLOITATION OF DG

From an economic perspective, the use of DG has clear attractions, but the current DG market is under-exploited. This is mainly for technical reasons, but standing alongside these are regulatory and commercial issues.

For a range of technical reasons, once penetration reaches significant levels (say, above 20% of load on a feeder), DG is unwelcome to network companies in many situations because of the increased technical problems in relation to system reliability. Allied to this constraint is the need for a diversity of DG types in order to supply local network loads with sufficient security, particularly in the case of wind and solar renewables due to their intermittent nature. Finally, added to the penetration level and diversity constraints, there is the need to integrate the output capacity of each DG technology employed.

In examining likely DG penetration scenarios, the focus thus needs to be on what will drive generation investment in the future and what will influence changes in thinking to bring together the new generation technologies with the older and proven technologies. The current delivery model has served New Zealand well, achieving continuous improvements in reliability, and reduction in costs through economies of scale and competitive market efficiencies. As a consequence, however, there are significant entry barriers for new DG technologies, including existing low marginal and sunk cost, long-life infrastructures, and current consumers' expectations of price and service. These market influences are summarised in Table 4.

It is self-evident that DG presents a challenge that will require investment in technology to enable safe control and dispatch in a multi-directional flow network. The few current examples of DG in New Zealand are not really a basis for a future blueprint because their context is today's electrical systems where the emphasis rightly remains on ensuring a safe, reliable, high-quality service from a uni-directional flow network.

Most network companies will have to rebuild the majority of their systems over the next 20-30 years, assuming that the major capital investment was between 1950 and 1970. Rebuilding networks in such a way that they can accept DG solutions must be seen to be prudent expenditure and recognised in company asset reporting.

DG can also provide a step-wise approach to managing the risks of investment in generation projects. However, current regulatory frameworks act as a disincentive to some forms of investment. Separation of generation and retail businesses can potentially impede DG investment when modern procurement practice is towards partnership arrangements to minimise risk, such as BOOT (build, own, operate and transfer) and other forms of financial risk management. Project financing is the most risky form, and ultimately a market structure that disallows risk sharing between the generator, network owner and the retailer can only drive up energy costs.

In addition to efficient investment, added value should be created for all parties. This requires a significant change in thinking from current paradigms towards more innovative engineering and contractual solutions. There has to be a better understanding, by all participants, of large-scale electrical system design, operations, and cost recovery mechanisms. Communication and knowledge are the key to understanding and reaching consensus on all these perplexing issues. Certainly on technical issues, DG gives the industry a fresh challenge to revise itself and embrace the full benefits that DG can bring to servicing consumer energy needs.

TABLE 4: MARKET INFLUENCES ON DG UPTAKE

GENERATION	TRANSMISSION	NETWORKS	RETAILERS
• $10 bn+ of sunk assets • Low marginal costs • Revenue risks & competition	• $2 bn+ of sunk assets • Low marginal costs • ODV at risk and regulation	• $10 bn+ of sunk assets • Low marginal costs • ODV at risk and regulation	• $1 bn+ of sunk assets • High marginal costs • Profitability and competition
Cashflow security on investments	Security & asset optimisation	Reliability & asset utilisation	Minimising costs & market risks

The future DG market can best be described as an engineered outcome driven around market needs. The critical characteristics of the future DG market are:

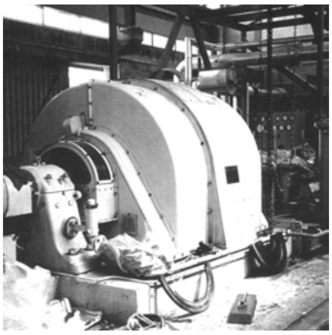
- matching changes in demand and supply capacity of networks in a more efficient and more 'distributed' way
- providing specialised energy products and services direct to customers
- use by the supply (generation) market of smaller, more fuel-efficient and lower-cost investment plant
- providing higher-quality environmental benefits from fuel to energy conversion
- taking up the opportunity of fuels that are essentially free (e.g. wood waste and landfill gas)
- serving needs other than electricity generation (e.g. technology demonstration, asset investment deferral or multi-purpose project).

DG is not, however, a replacement for wholesale market-supplied energy. DG is in essence a different market, complementary to the wholesale market, with each providing different cost structures and benefits. For example, a secondary DG market can be envisaged involving on-selling or buy-back of surplus electricity capacity. The degree of DG uptake alongside the wholesale market supply from large electricity generators will depend on location and specific drivers at an application level.

MANAGEMENT OF ENERGY RISKS

Increased interest in DG is coming at a time when there has been a shift in energy price risk from generators and retailers to customers. Up until recently, few customers were exposed to energy price fluctuations except when they renegotiated electricity supply contracts once a year. Today many industrial customers have a part or all of their electricity demand exposed to spot prices. Because the electricity market is based on export prices (that is, the price is only known after the event), the customer may face high electricity prices, which they only know about the following day. Until the electricity market moves to ex-ante pricing (that is, when the price is set ahead of the period to which it applies), industry will not be able to fully manage its energy costs.

Through investment in DG, energy users can hedge at least part of their energy demand and be less exposed to severe electricity price fluctuations. In a dry year, when spot prices can be very high, the generation of electricity from a DG facility will for many technologies be much less than the spot price. For example, when the spot price goes above about 20 cents/kWh, it is cost-effective to run a diesel generator.



NETWORK INCENTIVES

The introduction of DG has technical implications for the design and operation of distribution networks. These can generally be solved, but at a cost. If small-scale DG becomes widespread these technical implications become significant, particularly in respect of the safe operation of electricity networks.

There are also commercial and regulatory issues to address in relation to the connection of very small embedded generators to the network. The introduction of DG will not always reduce the costs of the network owner, and is just as likely to increase them. There is no general rule and the pricing arrangement needs to provide the appropriate financial signal to encourage DG owners to connect to points of the network where the total costs to all parties will be minimised.

Overseas, there is reluctance for distribution network owners to look to solutions other than network augmentation to address network constraint problems. Overseas evidence suggests that to encourage the use of DG, the regulatory regime needs to provide the right incentives so that alternative solutions to network constraints, such as embedded generation, are used where these are economically efficient.

In New Zealand, the anomaly remains of line charge recoveries which differentiate between a generator which is traditionally required to pay the full cost of network augmentation (including any augmentation required of the shared network) before being allowed to connect, and an off-take customer who is only required to pay a ‘shallow’ connection charge based on the direct cost of connection, with any shared network augmentation costs being recovered through ongoing use of system charges.

governance and regulatory framework

A critical component of the risk factors likely to influence DG uptake is the governance and regulatory framework within which the electricity sector operates. Deregulation of the sector has already accelerated investment and development of smaller electricity generating plants embedded in distribution networks, but these opportunities are under-exploited and constrained by current industry thinking.

DG is not a market that can be regulated for or prescribed. The regulatory regime required is one that does not skew investment efficiency but instead seeks to create a level playing field so that grid-based generators are not favoured over DG opportunities. To do otherwise will only lead to inefficient investment and energy costs that are higher than necessary. The potential market will be strongly influenced by such factors. Thus there is a need to understand better the degree to which pricing, market rules and technology performance will act to constrain the uptake of DG and so determine the future economic viability for DG in New Zealand.

DG is widely perceived to constitute a threat to the conventional participants in the electricity industry. In reality, it presents an opportunity to better allocate supply and price risk in an increasingly volatile energy market. However, this requires integrated policy as well as integrated planning.

REGULATORY FRAMEWORK

The business environment for the uptake of DG is strongly influenced by the present regulatory framework in New Zealand. Deregulation of the electricity generation industry has already prompted investment in smaller generating plants embedded in distribution networks. Examples include geothermal and co-generation in some of the country's larger industries. However, there are commercial and regulatory issues to address in relation to having a large number of very small-capacity embedded generators.

For instance, a generator directly connected to the transmission grid may make only relatively small payments to use the national grid whereas connection into a local distribution network may attract a larger capacity charge depending on location and network utilisation. Some network companies, however, do pass on to DG operators some of the network savings from the installation of DG. Thus an issue arises around the inconsistency between network companies and the difficulty DG investors have in being able to assess costs at the preliminary stage. Such matters have an important bearing on the penetration potential of DG and who the players will be in bringing DG to the marketplace.

Mixed in with these primary issues are the apparent disparities in commercial behaviour between the different segments of the industry. Some of these differences can be traced to shareholders' attitude and governance structure. Other differences appear to be simply due to a lack of experience in addressing DG. Another important contributing factor, sometimes overlooked in respect of DG because of its localised effects, is the nature of the network asset base and its current utilisation factor. The more static population centres contrast with those centres with increasing populations and related infrastructure demands. When network company shareholder focus is on developing the network and hence increasing the asset base, the methodologies used to determine connection charges can be less favourable for DG. This is clearly a market driver away from optimum economic decision-making.

GOVERNANCE

Shifts in government policy can also make an enormous difference to the uptake of DG. For example, Transpower, as the de facto regulating body on transmission matters, is currently in the process of reviewing its transport agreements. Of paramount importance, therefore, is how the proposed Electricity Governance Board (EGB), as the electricity industry's regulator, takes an active interest in these issues.

Specifically, the determination under the EGB of how best to reconcile the distorting effect on allocating interconnection charges based on either peak or average regimes will have a major impact on DG uptake. Transpower's policy to promote any form of investment through efficient pricing for sunk, fixed and variable costs, although sound in theory, has practical repercussions. An effective framework for new investment in DG goes beyond just the transmission network through to reticulation networks and retailer connections.

Network companies risk the consequence of price controls being imposed under Commerce Commission scrutiny if they breach certain specified thresholds relating to financial and other performance measures. Thus regulation can act to constrain optimum decision-making and create a barrier to rational DG investment.

From a national perspective, it is essential that the network companies have a good knowledge of the incentives for DG investment so that the wider industry can make the paradigm shift towards a far greater adoption of DG. If this is not recognised, or if other special means of encouragement are not made (similar to government strategies on energy efficiency and renewable energy), the business climate will be unfavourable and the penetration of DG to any large extent will be constrained.

Electricity network companies can encourage the uptake of DG, but few undertake this positively at present. It is evident that a network company has incentives to act in a positive way to DG when it can lessen peak demand charges and avoid network reinforcements required to satisfy increasing load demand, but this requires wider co-operation with other industry partners. Unfortunately, the corporate separation that now exists between industry participants makes co-operative participation complex and serves to increase transaction costs.

At present, Transpower includes DG in a limited way in its network planning but it is difficult to include projects that may or may not proceed, and over which it has no control. Forecasting is done using econometric models based on a supply/price relationship for different market segments. The need, however, is to look to mechanisms that would encourage solutions other than network augmentation and that could enhance system security and reliability. This would address the situations where DG is treated as a cost to the network operator, and where pricing arrangements do not provide appropriate financial signals to the embedded generator.

There needs to be a pragmatic, nationally consistent perspective that enables the sharing of the network benefits of DG, rather than a reliance on protracted negotiated agreements between a number of parties in which there are winners and losers, but which invariably become too difficult to bring about. The former approach would provide potential DG investors the ex ante network cost information that they need in order to evaluate projects fully.

NODAL PRICING

Energy prices at a particular Transpower grid location, or node, are set by the marginal cost of generation required to meet the demand of that node. The potential DG investor has the choice of investing and sharing the nodal price reduction benefits with non-contributory, free-rider third parties, or waiting until another party makes the investment to reduce nodal prices and then become a free-rider themselves.

The absence of any capacity for Transpower to invest in alternatives to the distribution grid effectively acts to discourage investment in DG by third parties. Northland is an example where significant investment in DG would potentially result in reduced nodal pricing at Northland nodes. However, once the investment was operational, the nodal price would drop because of this injection of generation. Consequently, this would make the investment appear sub-economic (unless the project is backed by other financial instruments such as hedge contracts), when in reality the DG investment would be a significant strategic investment for the investor and would provide regional supply security benefits. In other words, a transmission constraint problem would be solved by DG yet the investor may not be able to capture all the economic benefits because of an inappropriate commercial regime.

This paradox is reflected in Table 5, where the issues are compared. A key factor is the scaling of generation capacity to exactly match constraints.

SECURITY OF SUPPLY

Where parts of the supply system are old, inadequate or no longer appropriate, DG provides an opportunity to strengthen security as an alternative to new transmission lines. The reliability factor of this security is enhanced when the DG is dispersed in a number of small units of capacity – more so than from having the total capacity provided by only one or two large DG installations. Ultimately, down at the individual domestic customer level such as can be achieved by micro-CHP, DG potentially offers the highest level of security, both from a network and from an end-user perspective.

A surprising contribution can be made by small-scale thermal generating plants, particularly from emergency diesel stand-by plants. By contracting this DG generation to operate when called upon, the major generators can lower lake storage more in winter yet provide the same level of security because of this reserve DG capacity. If hydro operators take up the reserve DG opportunity it would be possible for them to increase hydro utilisation, capturing an estimated five-fold increase in value from the hydro energy (which displaces fossil fuel-fired generation) compared with the quantity of assumed diesel that would be used for the DG. The reserve generation is thus transferred from hydro to DG.

In these ways, DG solutions can overcome traditional transmission and distribution lines problems. In many rural areas, for example, seasonal electricity demand diversity is a significant management issue which is compounded by increasing service levels demanded by customers as rural operations become more technically sophisticated.

The same trends are occurring in the industrial sector. The fact that contracted interruptible load has increased over the last seven years from 150 MW to 550 MW indicates a shift in patterns of electricity use from historical trends. The flexibility may be there, with customers willing to comply with load interruption at times of a system contingency, but the means of harnessing it is not.

These trends together show how much patterns of energy use are shifting and how conventional supply paradigms are unable to cope with significant changes. From a systems

TABLE 5: **KEY DIRECT VS EMBEDDED ISSUES**

GRID CONNECTIONS		EMBEDDED CONNECTIONS	
Physical • Technical requirements of connection • Poor scaling for nodal market	Financial • Connection costs • HVdc charge in SI	Physical • Auto re-close may require synchronising capability • Better scaling for nodal market	Financial • Possibly avoided interconnection charge – which is inefficient • No credit for maintaining security of supply

security perspective it is also apparent that the New Zealand energy sector does not have the degree of co-ordination or co-operation between energy retailers and network companies to most effectively respond to these challenges. As a result, many potential business opportunities are only given vague consideration amongst potential DG owners and investors, if at all. Integrated solutions are needed to recognise that viability does not depend on energy value alone and that one action can often create another opportunity.

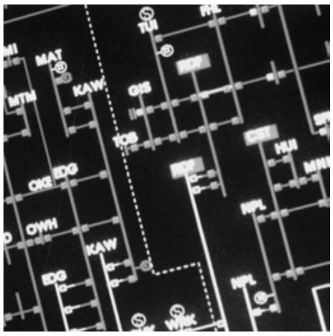
DEMAND MANAGEMENT

Demand management is part of the concept of DG as, in many cases, DG investment has been solely investigated because of on-site demand management considerations. DG is a key tool of on-site energy management.

From a regulatory perspective, demand management is virtually ignored and in many situations actually creates barriers, or at best does not encourage investment. This is primarily manifest in the lack of a market for industrial site owners to sell back or on-sell surplus electricity commitments. For example, a site with a fixed volume electricity purchase contract should be able to sell on a secondary market any contracted electricity not used. From a DG perspective, this secondary market could be used for the sale of excess on-site generation.

DG USED AS A POWER STATION

DG is often treated as if it were a power station selling into the national grid. The DG generator may have to confirm generation with the national grid operator up to three hours ahead, just as wholesale market generators have to do. If a DG facility is embedded into an industrial site, then the level of generation should be of no relevance to the national grid generator as the output of the DG facility will be determined solely by site process requirements which often cannot be predicted more than three hours ahead. The fluctuations in demand for electricity from a large industrial site may be of consequence, and communication between the site generators and the national grid operator may be valuable for maintenance of grid supply security. However, this is a function of large demand loads and if DG is within this, the DG facility should be considered beyond the interests of the national grid generator.



the new zealand opportunity for DG

THE ROUTES FOR DG UPTAKE

Fuel supply issues are likely to dominate the economics of DG facilities just as they do for large centralised power stations. New Zealand is an energy-rich country, but the structural barriers associated with primary fuels production means that the time of cheap energy is past. Furthermore, the implications of greenhouse gas emissions from conventional thermal electricity generation means that the challenge of future fuel selection will become more complex involving trade-offs between commercial, environmental and technical characteristics.

For most people in New Zealand, access to energy (and cheap electricity) is taken for granted. There has been an historical close coupling between economic growth and energy demand growth, and people's expectations are that energy suppliers will continue to meet their future personal and business needs. The reality is different, reinforced by the pending depletion of the Maui gas field and increasing risk of energy shortfalls in the near term during the transition to alternative fuel sources. New Zealand is thus at a crossroad where major decisions will need to be made involving significant new investment in energy supply systems. The role of DG in this future is thus a critical issue.

There are three possible routes in the near term:

- a continuation of current trends based on embedded generation using conventional technologies and supplemented by limited additional investment in co-generation
- a second investment stream of small scale renewable energy generation facilitated by supportive government policy and market mechanisms
- a future 'engineered' market driven by capacity and access arrangements, and characterised by information and key electronic technologies required for sophisticated electricity supply management and control to every customer.

These routes overlap and can merge together or they can remain separate. The investments in DG now being made thus provide a pathway to full integration of all three streams. The next wave of investment anticipated is by way of assisted renewables based very much on conventional technology growth paths. The third stream of investment from an engineered market is emerging but full uptake will be dependent on regulatory and industry behaviours. The establishment of an active engineered market will be an essential condition if the full potential for DG opportunities is to be realised.

Each of these routes are characterised in terms of how they might contribute to New Zealand's electricity market in the matrix described by Table 6.

An engineered electricity market is emerging, driven by strong and widespread consumer dissatisfaction with current wholesale market solutions. This dissatisfaction is causing customers to look for improved access to the marketplace and to involve third parties to manage the complex contractual arrangements that characterise the electricity market environment.

The issues that will influence DG uptake centre on dealing with the complexity of the number and type of energy sources, changes in electricity transmission flows, maintenance of local reliability and security, and market integration. The issues are not insubstantial, but it is the solution to these issues that will reshape the electricity supply industry and the way in which the sector is now organised. The fragmentation of the industry as it now stands, and the complexity of current relationships and market mechanisms, will require a paradigm shift in thinking if the sector is to evolve to meet this challenge.

PENETRATION SCENARIOS

The penetration of DG in New Zealand is driven by:

- niche opportunities for supply based on available waste fuels or renewable sources
- meeting business on-site energy requirements
- more efficient responses to meeting the demand and supply capacity requirements of networks

TABLE 6: **THE DG MARKETPLACE**

THE OPPORTUNITY	THE TECHNOLOGY	CURRENT MARKET	FUTURE MARKET
Current trends	reciprocating engines gas turbines combustion/steam turbine geothermal	asset utilisation system security	asset utilisation system security price hedge
Assisted renewables	small-scale hydro biomass systems wind solar water heating	embedded systems (local)	capacity contracts system security (national)
Engineered market	smart metering real time pricing ICP switching remote control integrated energy management systems	emerging market	open access provider contracts and customer manager

- incremental investments to meet power quality and stand-by capacity markets
- renewable energy/carbon trading opportunities
- customer dissatisfaction, in the longer term, with existing market access arrangements.

Overseas developments indicate that uptake in each country may have different dominant drivers. For example, DG uptake in the UK is dominated by a drive for renewable energy. The key issues and specific factors that will influence penetration into the New Zealand market are summarised in Table 7.

Penetration scenarios describing the possible generation of electricity from DG are set out in Table 8. These scenarios assume that the current direction of the reforms and restructuring of the energy markets remains, but recognise the new thinking and systems approaches necessary to migrate from current conventional DG forms into a fully engineered market with outcomes driven around needs.

The scenarios do not include the potential contribution to New Zealand from investment in heat plant or other DSM responses (for example only the electricity component of a co-generation facility is included). Significantly more study is required to get to this level of detail. The current and assisted routes are combined to offer a perspective of the likely indicated and proven contribution from DG. The engineered market route extends these estimates significantly with the quantities presented inferred on the basis of the descriptions provided below.

Reciprocating engines

There is significant existing installed capacity of DG, predominantly using stand-by diesel or gas reciprocating engines which can be encouraged to participate in the energy market at times of system peak. It is estimated that the total capacity may be as high as 300 MW, of which approximately 10% is assumed available as a DG source under current trends. In an engineered market scenario, it is anticipated that much of this capacity could be encouraged on-line with some new plant installed to be upwards of 250 MW or about 3% of New Zealand's total installed generating capacity. An engineered electricity market would provide greater financial incentives for plant owners and provide communication tools that would expedite operation as DG plant.

Gas turbines

Existing installed capacity of this technology is dominated by North Island co-generation, particularly in the dairy industry based on natural gas feed. Current total installed capacity is of the order of 250 MW. Current and projected future constraints in the North Island gas market will limit further expansion of this technology unless a major new gas field is discovered and brought into

TABLE 7: **THE DG MARKETPLACE**

DG OPPORTUNITY	COMMERCIAL FACTORS	REGULATORY FACTORS	AUXILIARY FACTORS
Current trends	proven and well-known technology plant flexibility and relocatability fuel flexibility price recognition for location value and diversity asset utilisation	regulatory arrangements for non-utility generators interconnection rules nodal pricing	environmental performance uncertain gas market dynamics scale too small for significant impact on capacity building community acceptability
Assisted renewables	non firm capacity high capital investment /operating costs plant reliability delivery costs to load centres reliability of fuel supply	Carbon tax /GHG incentives RMA grid access arrangements ODV at risk for network companies	network pricing regimes technical risk, and safety increased network losses
Engineered\market	cashflow security negotiated agreements technological risk collaborative business models	industry regulatory structure to enable risk sharing system dispatch and integration	integrated energy solutions changing customer end-use patterns customer dissatisfaction with market outcomes

TABLE 8: **PENETRATION SCENARIOS FOR DG**

THE TECHNOLOGY	CURRENT AND ASSISTED ROUTES	ENGINEERED MARKET ROUTE
reciprocating engines	20 - 40 MW	250 MW
gas turbines	0 - 20 MW	50 MW
combustion/steam turbine	40 - 80 MW	100 MW
geothermal	20 - 80 MW	100 MW
small-scale hydro	10 - 30 MW	80 MW[1]
biomass systems	0 - 5 MW	10 MW
wind	5 - 20 MW2	160 MW[2]
maximum projected installed capacity	95 - 275 MW	750 MW

1 Not fully constructed by 2015.
2 Annual capacity factor output, i.e. up to 3x these figures in terms of maximum rated output.

production. Presently identified gas fields, when brought into production, will open the way to using gas turbines, but the possible penetration will still be small. Future deployment of turbine technology may well be distillate-based at capacities of 1 - 5 MW. As the number of industrial players in this market is small introduction of an engineered market is unlikely to greatly influence uptake. Packaged microturbines now entering commercialisation will challenge the supremacy of reciprocating engines, especially in applications where heat recovery is possible, but their scale (100-200 kW) will require large numbers to be installed in order to make a significant impact nationally.

Combustion/steam turbine

In the industrial (and to a very limited degree the commercial) sector, any increased uptake of electricity production from DG will be integrated with investment in new heat plant. Currently there is about 40 MWth of heat plant capacity being installed annually in the forestry and dairy industries, but since the late 1990s there has been no provision for electricity generation included with these investments. A continuation of the requirement for additional heat capacity is anticipated, particularly in the wood processing industries. Increased gas prices and government assistance to renewable energy are expected to improve the economics of co-generation, particularly from woody biomass. However, total installed capacity will be limited by manufacturing scale and total heat demand. In the New Zealand context this will limit generation levels at individual sites to an average of about 5 MWe. An engineered market might encourage some existing industry sites generating steam to turn to self-generation, but the opportunities remain limited.

Geothermal

The inherent reliability and flexibility of geothermal power makes it a valuable component of electricity and heat supply systems. Current installed capacity is approximately 400 MW. However, overall efficiencies of geothermal generating plant are only of the order of 10% and for DG applications, direct heat use is the preferred option being much more efficient than electricity generation. Limitations on transport distance also mean that accessible geothermal energy is very localised, and geothermal development is most likely to be directed to large centralised electricity generation. The opportunities on a DG scale will be quite low and limited to situations where a user exists close to a geothermal resource and has the technical capacity to utilise binary heat plants. The engineered market scenario will have very little effect on encouraging greater geothermal utilisation under current trends.

Small-scale hydro

This is an area of strong interest and activity at the DG level. Existing installed DG capacity is estimated at about 80 MW (excluding dominant generators). Taking into account the influence of drought-prone areas, potential is estimated at around 350 MW, although evaluation and consenting of these opportunities are likely to constrain the degree of uptake up to 2015.

Significant economic benefit can be realised where small-scale hydro is developed in unison with wind power generation. The ability to increase 'storage' potential and de-couple wind generation from wind speed factors creates a premium value. This potential is most likely to be picked up in an engineered market, thereby more than doubling the otherwise limited expected contribution from this source.

Biomass systems

The utilisation of woody biomass residues from the forest industry is included within the combustion energy stream described above. Outside this source, other biomass opportunities include landfill gas and digestion of organic residues to methane. Current generation capacity from these sources is of the order of 25 MW. These are niche opportunities limited predominantly to sewage works, landfill operations and food processing industries. Some limited contribution is provided for as New Zealand moves to develop better-engineered landfills and with encouragement from government assistance to renewables.

It is expected that biogas from waste processing will become more common as environmental standards increase. The greatest growth is expected to occur in the dairy farming sector, but is not likely to be significant in the period up to 2015.

Wind

Wind development both for DG and grid-connected wind farms is at the point of economic viability. The wind resource at selected sites is high by world standards and a high capacity factor is generally assumed although there will be some reduction to current delivery as less favourable sites are developed. Existing installed capacity is approximately 40 MW with a further 70 MW either announced or known to be in the planning stages, although it is linked to centralised electricity production modes and is not truly DG. In the engineered market, however, DG opportunities are expected to emerge as experience develops and the value of wind is recognised as part of a total energy solution. Although a rapid increase in demand may result in long delivery delays for the larger machines and investigation and consenting processes are likely to slow uptake, significant investment levels are anticipated subject to access arrangements and third-party contracts being accepted in the marketplace.

Solar

Uptake of photovoltaic electricity generation is not expected to increase beyond niche applications in the period up to 2015, but solar hot water heating coupled with enabling technologies such as ripple control is expected to become more prevalent. The degree to which it can be recognised as DG is difficult to estimate.

conclusions

DG now permits a paradigm shift in thinking about delivering local solutions for meeting individual consumer energy needs. There is no longer any need to rely on utility solutions and industry trading arrangements to meet expanding requirements. Instead, niche opportunities are arising that will offer customised solutions and improved access to reliable and firm electrical supply. DG can fundamentally change electricity investments at all levels of the supply network.

This potential has arisen because of the ongoing improvement in the technologies used for electricity generation and because of the changing structure of the electricity industry, which has more clearly delineated the supply and price risks associated with generation, distribution and retailing of electricity.

DG has the potential to reduce the supply-demand gap emerging in New Zealand's electricity supply as well as providing an alternative to expanding the capacity of established electricity transmission and distribution networks. DG can also alleviate constraints on the development of new hydro and the supply of natural gas by providing a more diverse energy base for electricity generation. In doing so, there are economic benefits from DG through providing peak shaving and stand-by capacity in response to an increasing volatility in electricity price and the need to hedge against high energy costs.

DG is more widespread and entrenched than generally recognised. Proven DG applications span a wide range of technologies, capacities and energy sources, and there are both financial and risk management drivers for investment within the current industry structure. However, in today's regulatory and industry environment, the benefits of DG are difficult to realise. In many instances, DG values are not recognised and investment is actively discriminated against at times. With the industry now divided into so many separate legal and commercial/shareholder entities, the commercial and regulatory problems are many and various.

Realisation of DG's potential will thus involve greater market complexity, not simplification. As we have developed our thinking throughout the study it has become clear that the trends are for a future engineered DG market driven by strong and widespread consumer dissatisfaction with current wholesale market solutions. This dissatisfaction is causing customers to look for improved access to the marketplace and to involve third parties to manage the complex contractual arrangements that characterise the electricity trading environment.

In future, individual customers will be served via new businesses offering standard protocols and technologies for energy management at the consumer end. This will happen within the constraints of the existing physical network and systems infrastructure. Redundancy of existing systems is unlikely and continued reliance will be placed on large-scale wholesale electricity generation and supply for firm capacity and price moderation. The investments now being made in DG, based upon the conventional technologies of reciprocating engines and co-generation, provide a pathway to the introduction of the new industry arrangements needed to support DG to the fullest extent.

It will be critical to the future of DG that this opportunity is recognised and supported by government policy. DG is not a market that can be regulated for—it is the special characteristics of the New Zealand electricity market that will determine uptake. Although the next wave of DG investments is likely to be small-scale renewable energy generation facilitated by supportive government policy, the key to DG's future will be migrating from the current policy framework to new arrangements that encourage systems-level interventions that focus on the interface between DG and the network systems to which it will be connected.

The uncertainties influencing this migration to an engineered DG future are manifold. Considerably more thinking and analysis will be needed before New Zealand is ready to bring together coherent strategies for action. Vital issues include:

- overcoming the market rule barriers to DG
- optimisation of DG within the New Zealand transmission network
- matching DG investment with dynamic pricing regimes
- establishing methodologies for access of DG projects at a systems level
- establishing standardised approaches to negotiations and applications for connection
- new innovative thinking on trading arrangements for allowing intermittent sources of generation
- establishing methodologies for including DG and demand-side management in asset valuations
- quantifying the costs of connecting DG from remote sites
- managing and regulating safety issues.

The task is now to reveal DG opportunities and encourage projects to be developed jointly by suppliers and consumers that will offer mutual benefit and opportunity. From the point of view of electricity security and investment, the focus should be on creating new value streams through incentives for least-cost solutions, and establishing economic incentives for efficient investment in grid or grid alternatives.

appendix: case studies

At the core of the study that led to this paper was the use of case study analyses of commercial DG applications to identify opportunities, economics, risks and probability of uptake of DG technologies. Case studies were of real-situation DG applications that allowed a range of DG types to be put under the microscope, examining what had been the drivers for these projects, what had been the technical and economic factors that had resulted in a 'go' decision, and what had been the social and environmental issues that had been of importance. Thus the major variables were identified from which to learn more about the factors likely to shape New Zealand's future electricity supply.

The data used in these examples were generously provided by the companies involved and cover a range of different DG applications, some of which are successfully developed and some with strong potential.

The case studies were:

- Opuha hydro generation (integration into rural network, local communities)
- Christchurch peak reduction (back-up diesel generation to avoid distribution lines upgrading)
- Stonyhurst remote homestead (isolated rural supply)
- Windflow wind turbine (fluctuating load on weak rural system and to give insights into the early planning issues)
- Gisborne and East Cape Networks (regional spur with alternative generation to avoid transmission upgrade)
- Kinleith Co-generation facility (market and dispatch related issues)
- BP service stations (solar panels on service stations to reduce purchased supply)
- Kumeroa rural farming (voltage stability issues and technology options, islanded vs distribution back-up).

A consistent analysis framework for evaluating DG opportunities was applied to each of the case studies, including:

- identification and examination of drivers and impediments to the success of DG projects
- identification of circumstances under which DG can be utilised
- estimation of the potential market penetration for using DG
- development of an understanding of technologies in different circumstances
- comparison of different DG technologies and their risk profiles.

Each case study probed why and how the particular project was implemented. By doing this, the main economic or strategic drivers for the project were identified. In addition, any risks associated with the project were identified and, if appropriate information was made available, the economics (costs and revenues) revealed. Some of the opportunities and risks may have been similar from one case to another or quite different depending on the organisation that implemented the project, the technology and fuel used. However, by looking at various cases, a good insight was gained into commonalities that apply to DG.

case study 1: kinleith cogeneration facility

BACKGROUND

This case study gives a useful insight into the issues associated with industrial co-generation on a large scale.

In 1993 the Carter Holt Harvey (CHH) pulp and paper mill at Kinleith produced about 450,000 tonnes of pulp and linearboard. Steam is an essential component of the Kinleith production process and was supplied from two recovery boilers burning black liquor, two wood waste boilers and the remainder from a gas boiler. The plant had recently gone through a modernisation programme.

The cogeneration project was established primarily to overcome air emission resource consent problems. It would also utilise excess wood waste being dumped in the forest. The project provided an added benefit of producing some electricity at a known acceptable price.

At the end of 1993, the old #2 and #3 wood waste boilers' environmental consents lapsed. NZFP, who then owned the pulp mill, had been allowed by the local authority to continue operation on the understanding that the old wood waste boilers would be shut down when alternative arrangements were put in place. The shut down of the #2 and 3 boilers would have meant that the wood waste from the mill which would otherwise be burnt would have to be trucked away and dumped.

Various options were initially considered including burning additional gas and drying wood, building a new high-efficiency wood waste boiler, fitting precipitators to the existing wood waste boilers, and installing a gas turbine plant with heat recovery.

The cogeneration plant, to be supplied by ECNZ, was intended to be an integral part of the mill operation. Generation of electricity without the mill being in service is not possible. Electricity generation is considered a by-product of the mill operation and for on-site use.

The construction and commissioning of the cogeneration facility has stopped land filling of wood waste, reduced atmospheric emissions from the mill (compared with using the previous wood waste boilers), and reduced purchase of natural gas fuel by the plant operator.

United Networks share the Transpower GXP connection with CHH but do not supply the CHH Kinleith site with services. Its interest is to minimise costs and maximise quality of service to other customers served by the GXP. The cogeneration plant is used to achieve these goals.

DESCRIPTION

The facility comprises a new woodwaste and gas fired boiler, and a pass-out back-pressure steam turbine generator.

The basic features of the cogeneration facility are:

- A new boiler rated at 100 tonne/hour on woodwaste and 180 tonne/hour on combined woodwaste and gas firing, or gas firing alone.
- Fuel handling equipment for the woodwaste, which consists mainly of bark and chip fines.
- A new steam turbine which utilises the steam from the two existing chemical recovery boilers as well as from the new boiler. It can supply up to 170 tonne/hour of steam at 450 kPag and 309 tonne/hour of steam at 1250 kPag for mill processes, and provide up to 40 MW of electricity from the attached generator.
- A steam bypass system to ensure that the mill is supplied with steam when the turbine is shut down for any reason.

The steam output from the cogeneration plant is determined by the process needs of the pulp and paper mill, and not by any electricity generation considerations. The two existing black liquor-fired recovery boilers and the new boiler are connected to a common 4500 kPag steam header providing steam to the 40 MW steam turbine. The steam from the new boiler is produced primarily from the combustion of woodwaste, but natural gas is used for quick response to steam load changes and to supplement the woodwaste fuel. The plant generates electricity by utilising the reduction of the steam pressure from the boiler pressure to the process pressures.

The cogeneration facility is treated within the electricity market rules as a power station because of the size of the generator. This is despite the fact that under usual operation the export from the site is under the 5 MW threshold required for generators to be covered by the market rules.

TABLE 1.1: **SUMMARY**

COMMERCIAL RATING	EXTERNALITY ISSUES	REGULATORY ISSUES
high	Need for waste disposal. Other factors were plant steam balance. Environmental consents required for plant to operate.	NZEM rules compliance. Integration with local load shedding.
ENERGY SOURCE	**ENERGY USE**	**CONNECTION**
constant	on-site/ export	grid

TABLE 1.2: **GENERIC ANALYSIS**

GENERIC CASE	COMMERCIAL ISSUES	EXTERNALITY ISSUES	REGULATORY ISSUES	NEW ZEALAND SPECIAL FACTORS
Bioenergy	Availability/ cost of fuel. Need for waste disposal. Use for heat on or off-site. Principally a heat source.	Air and noise emissions.	Solution for environmental problems. 40 MWth installed annually (for timber drying). Scale issue – too small for viable electricity generation.	Growing source of wood, log exports produce waste. Competition for fuel from garden centres. Unlikely to be investment in NZ in large integrated wood processing facilities

case study 2: gisborne and east cape networks

BACKGROUND

This case study gives a useful insight into the issues associated with operating remote rural regions.

Eastland Network (ENL) supplies electricity to the Gisborne/East Cape area. The Gisborne/ East Cape area has a single double-circuit 110 kV transmission line bringing electricity into the region from Tuai which is considered to be constrained because of security requirements set for the line.

ENL has developed a strategy to overcome that constraint and avoid in the short term the need for a new line proposed from Wairoa to Gisborne. ENL has been focusing on improving its security of urban supply and reducing Transpower connection costs by reconfiguring the sub-transmission network. ENL then intends to focus on reducing its daily peak load and, over the next few years, increasing supply capacity.

Distributed generation is part of the short-term solution to improve reliability and get the maximum benefits from their network assets. This will lead into opportunities for further generation as the area's energy demand increases. DG may in this instance may improve price signals and allow for economic and demographic growth and transformation.

DESCRIPTION

Tuai - Gisborne transmission capacity
The Tuai - Gisborne transmission line has a capacity of 62 MW. However, to meet system security requirements, the effective contingent capacity is 47 MW. This means that if one circuit is lost due to a fault, up to 47 MW of electricity can still be delivered over the other circuit.

The current uncontrolled maximum electricity load on the transmission line from demand in the Gisborne/East Cape area is 53 MW. ENL is, however, able to use load control to reduce the peak to 47MW. This means that the current transmission system is only just able to meet electricity peak demand and the Transpower Gisborne substation is already constrained. The priority is on immediately reducing peak demand in the area.

Electricity demand in the area is growing at an average of 4% pa. To meet this growth there will be a need to provide additional local generation capacity. Distributed generation options can provide capacity quickly while at the same time meeting reliability and peak lopping capabilities.

Gisborne - East Cape sub-transmission system
The Transpower 110 kV line from Gisborne to Tolaga has been removed from service and supply to the area is through the ENL 50 kV network. The local demand is around 4 MW. To constrain peaks, DG units will be installed at Tokomaru, Tolaga and Ruatoria.

TABLE 2.1: **SUMMARY**

COMMERCIAL RATING	EXTERNALITY ISSUES	REGULATORY ISSUES
medium	Keeps the electricity price lower in Gisborne. Regional benefits.	Recognition of DG in ODV and Transpower security calculations.
ENERGY SOURCE	**ENERGY USE**	**CONNECTION**
variable/constant	on-site/export	grid

TABLE 2.2: **GENERIC ANALYSIS**

GENERIC CASE	COMMERCIAL ISSUES	EXTERNALITY ISSUES	REGULATORY ISSUES	NEW ZEALAND SPECIAL FACTORS
Wind	Proximity to the network. Hydro system backup. Cumulative capacity constrained (20% of network load). Does not solve capacity constraint.	Area of outstanding natural beauty. Noise and visual impact. Site accessibility.	Shared benefits. Distributors can own unlimited capacity. Can connection into the network be made at no greater cost than to the national grid?	NZ is a small, long, narrow island, in roaring 40's, long coastline. Hydro system backup opportunity favours wind.
Hydro	Water priority for generation is secondary to its use for irrigation. Opuha irrigation was not bankable without generation. District water supply scheme is an area of potential – dam outlet & pipeline turbines, retrofit options.	Minimum flow in natural water courses. Wild river preservation. Paternalism – regional strategic growth vs parochialism.	Water allocation – no value placed on water. Long & difficult consenting process – expected that only 10% of potential could be realised for this reason. Excluded under current renewable definition. Conservation orders put resource off-limits.	Climate impacts generally. Irrigation needs. Cultural sensitivity to mixing waters. Water supply schemes match daily demand but not seasonal.
Fossil fuels	Fuel cost ability to respond to peak demand signal. Ability to parallel with the network Comparatively secure fuels.	Noise and air emissions. Co-firing with biofuel introduces renewable element.	Existing use provisions enable some type of generation. Local air quality plans are a potential spoiler. Gensets may be portable assets DG is an easy target.	Uncertain gas market dynamics. Substantial increase in gas price likely. Kyoto ratification. Large coal reserves.

case study 3: orion network

BACKGROUND

This case study gives a useful insight into the issues associated with distributed generation on a wide-scale with various fuel types and demonstrates that there are opportunities for deferring substantial distribution system upgrades.

Orion encourages up to 23 MW of generation from about 40 sites in the Canterbury region to provide local generation at times of peak load. This represents about 3% of Orion's maximum load. All these sites have existing installed generation capacity, mainly from diesel generators, to provide backup for their onsite use of electricity or to take economic advantage of a waste fuel source. In many cases, the increased reliability of supply permits the continued operation of the owners' core businesses.

DESCRIPTION

Orion has had a policy of actively encouraging demand-side management since the mid-1990s. The policy continues today, the strongest evidence of this being their delivery pricing structure and the mechanisms facilitating customers use of on-site generation to take best advantage of these pricing structures.

There are no particular constraints in the Orion network or Transpower network, but like all networks, as Orion's continue to grow it must spend capital expanding and reinforcing the network. Orion's current asset management plan forecast that $75 million will be spend on network reinforcements over the next 10 years.

The installation of a backup generator at the 40 or so DG sites will have been justified by each business such that the perceived benefits exceed the capital investment made. Therefore, the benefits must exceed the LRMC of the generator concerned.

In addition, two 640 kW/800 kVA diesel generators were purchased by Orion shortly after the Auckland CBD electricity crisis of 1998 and installed in locations within the Orion network where their peak lopping capacity would be of value. One is installed in Lyttelton and the second set is installed at Halswell District substation. The generators were justified on both the economic value of peak lopping and as an emergency backup plant. For instance, Lyttelton is a major port with strategic importance to Christchurch, both normally and in the event of an emergency situation to bring supplies on-shore. The Port Company also purchased an identical set of two generators with which it can maintain limited supplies to refrigerated containers and other essential services in the port.

The Orion generator sets, although mounted in fixed locations, can be moved relatively easily in an emergency if required elsewhere.
The generator sets are connected to dedicated 750 kVA 11/0.4 kV transformers. Environment Canterbury required resource consent for operation of these generators limiting noise and particulate emissions.

There are other generation sets connected to the Orion Network. Diesel stand-by sets predominate although there are two alternative type of generators on the network. The first is the Christchurch City Council's waste water treatment plant operating SI engines on biogas, and the second is the Ravensdown fertiliser works where surplus heat from its sulphuric acid plant (initially fired-up on diesel) drives steam turbines. Allied to this collection of generation sources, a number of hotels in the central business district have dual fuel capabilities and can contribute at times of system peak with the ability to fuel switch space and water heating loads to LPG.

The high cost allocated to system peaks is reflected in the level of payment made by Orion to such generators. Currently this price is $81.92/kVA/year. This encourages many with emergency stand-by sets able to be paralleled with Orion's network to come on- line during times of system peak and well compensates for the diesel fuel costs. Management of Orion's peak has so far enabled deferment of transmission capacity reinforcements.

Alternatives to fix the security problem (lack of N-1 security) into Lyttelton included an extra cable(s) via the rail tunnel at a cost of $1.2 million. The Orion generator sets are installed for keeping some supply security to Lyttelton should there be a line failure. There is a double circuit 11 kV overhead line on single poles with large spans either side of the summit of the Port Hills.

The signal to get the generator sets operating is sent out when Orion has already shed 60% of its controllable load and anticipates more will be shed. The signal also goes to the Ravensdown fertiliser works and the CCC Bromley sewage treatment works to bring in, or increase output and shed customer load.

Orion diesel engines are only used for peak lopping and they are not metered for energy sales. Only three of the listed generators are capable of exporting electricity to the distribution network. These include generators at Ravensdown and the two owned by the Christchurch City Council. Output from all other backup generators is used to reduce demand of electricity import to the site.

During control periods Orion estimate that 19.7 MVA of diesels operate and roughly 1/5 of Orion's deferred load comes from the running of the diesels. About 7 MW of generation has been installed in the last 10 years. In addition, a number of projects to synchronise existing diesels have also taken place.

As well as its own distribution network Orion has reduced Transmission capital expenditure, Orion's 'effective price' signalling provides benefits to the economy as a whole ensuring the appropriate use of scarce resources.
For example, over the last seven years Orion's load factor has improved from 50% to 60%, significantly reducing future capital expenditure. One specific example of this is that investment in a fifth transmission circuit from Twizel (costing about $80 million) has been deferred.

TABLE 3.1: **SUMMARY**

COMMERCIAL RATING	EXTERNALITY ISSUES	REGULATORY ISSUES
medium/high	Air quality issues	Consents required to move plant to new area of need difficult to obtain.
ENERGY SOURCE	**ENERGY USE**	**CONNECTION**
constant	on-site/export	grid

TABLE 3.2: **GENERIC ANALYSIS**

GENERIC CASE	COMMERCIAL ISSUES	EXTERNALITY ISSUES	REGULATORY ISSUES	NEW ZEALAND SPECIAL FACTORS
Fossil fuels	Fuel cost ability to respond to peak demand signal. Ability to parallel with the network. Comparatively secure fuels.	Noise and air emissions. Co-firing with biofuel introduces renewable element.	Existing use provisions enable some type of generation. Local air quality plans are a potential spoiler. Gensets may be portable assets DG is an easy target.	Uncertain gas market dynamics. Substantial increase in gas price likely. Kyoto ratification. Large coal reserves.

case study 4: stonyhurst remote homestead

BACKGROUND

This case study gives a useful insight into the issues associated with distributed generation on a small-scale, independent of the mains supply, primarily using a renewable resource.

Stonyhurst is a mixed farming property situated in coastal North Canterbury. When the property was subdivided for family reasons a new homestead was built on a headland overlooking Motunua Island for Peter and Fiona Douglas-Clifford. The chosen site would have meant extending the already long distribution spur to the original homestead another two or three kilometres, and also entailed crossing a deep ravine. These facts, coupled with frequent rural line outages in the area and a desire to become independent, led the owners towards installing a remote area power system (RAPS) for approximately the same capital cost as the line extension. The topography and purchase prices suggested that a wind turbine backed by a diesel generator offered the best solution to their energy requirements. Solar water heating was also chosen.

DESCRIPTION

Stonyhurst Station is situated on the coast off SH1, north of Greta Valley in North Canterbury. The station runs sheep and cattle, and supports some cropping.

The Rural Electric Reticulation Council (RERC) at that time was approached and subsequently a grant was awarded to offset part of the capital cost of the system components. Essentially these were a 10 kW Bergey Excel wind turbine on 20 m guyed tower, an underground 3-phase cable to a battery bank through a battery controller able to switch surplus power to hot water storage tanks whenever the battery was in a full state of charge, and a normal 230 V ac supply to the house from a single phase inverter/ charger, connected to an auto-start diesel generator set.

Though the wind resource is immense, the capacity of the installation is limited by the size of the inverter, sized at 4.5-5 kW and 87% efficient, and of the storage capacity of the system.

Grid or wind electrification were not the only options canvassed prior to installation.

The owners considered grid, diesel, solar and wind supply for their energy needs. Diesel and solar were discounted, on grounds of price to operate, and capital cost respectively.

The decision for wind power was driven in the first instance by the fact that there was very little difference in cost of grid extension and islanded supply with this technology, in view of the favourable price of the turbine.

The system is fully automated, though in the extreme winds sometimes occurring, the owners still find it preferable to furl the turbine blades manually. Routine maintenance of the system takes very little time; the owners check the powerhouse, a skid-mounted railway carriage housing the electronics and the battery bank, about once a week, mostly to ensure there is fuel for the diesel generator. They top up the batteries about three times a year. The site is also remote monitored by the Department of Mechanical Engineering of Canterbury University.

Visual impact of the grey tubular mast is minimal, and observable only from the homestead and its immediate surroundings, or from offshore. In haze or cloud, the tower and blades merge into the skyscape, and are hard to detect.

The household is equipped with every modern convenience, and the family has adapted to spreading their demand over the hours of the day. Cooking is done with gas, and there is an efficient wood burner for space heating.

TABLE 4.1: **SUMMARY**

COMMERCIAL RATING	EXTERNALITY ISSUES	REGULATORY ISSUES
medium	Rural supply reliability.	Increasing energy costs in the future. High capital cost of connection. Trend among rural people to buy diesel generator sets. Removal of cross-subsidisation, especially rural. 2013 obligation to supply time horizon.
ENERGY SOURCE	**ENERGY USE**	**CONNECTION**
variable	on-site	isolated

TABLE 4.2: **GENERIC ANALYSIS**

GENERIC CASE	COMMERCIAL ISSUES	EXTERNALITY ISSUES	REGULATORY ISSUES	NEW ZEALAND SPECIAL FACTORS
Wind	Proximity to the network.	Area of outstanding natural beauty. Noise and visual impact. Site accessibility.	none	NZ is a small, long, narrow island, in roaring 40's, long coastline.
Fossil fuels	Comparatively secure fuels.	Co-firing with biofuel introduces renewable element.	none	none

case study 5: opuha hydro/irrigation

BACKGROUND

This case study gives a useful insight into the issues associated with the dual use of water as a renewable resource.

The question of getting better access to water in the South Canterbury region has received considerable attention over at least the last 20 years. During the early years, a canal from Lake Tekapo to the Timaru region was proposed, but this was shelved by 1992 in favour of a dam being built at the confluence of the North and South Opuha Rivers. The advantages of the dam project were seen to be:

- summer irrigation to an estimated 16,000 hectares of farmland (including the economic benefits as a spin-off from the increased production of the farmland)
- an electricity generation scheme
- a lake for recreational use.

DESCRIPTION

In February 1994 Opuha Dam Limited (ODL) was incorporated, with the express purpose of being the interim entity through which the dam project would be financed and undertaken. Opuha Dam Partnership (ODP) later assumed that role, after some initial transactions had taken place through ODL. Construction started in 1995.

At the beginning of February 1997 when the dam was approximately half completed, a flood event overtopped the dam and caused significant damage and delay to the project. Roughly, one-third of the compacted fill material that had already been placed in the dam to be eroded and washed downstream – causing damage to roads, fencing and river protection works.

Construction of the dam recommenced later in 1997. Commissioning began by the end of 1998, and the dam has been operating at full efficiency since April 1999.

Plant

A 7.4 MW Francis turbine and generator takes water from Opuha Dam and passes out to a weir from which it is released for irrigation and to maintain river minimum flows. The turbine output depends on the storage lake level such that average maximum output is 6.8 MW. The generator has static excitation and a transformer stepping the output to 33 kV for connected to Transpower's nearby Albany substation.

Resource consents currently require a 1.5 cumecs minimum flow from the downstream weir. A minimum flow of 1.5 cumecs requires three hours generation per day.

Opuha is 15 minutes from Fairlie. It is possible to island Fairlie to supply 500 residents at about 1 MW output.

Water inflows

The Opuha dam sits at the confluence of the North and South Opuha, both of which rise in the adjacent mountains some of which reach 2000 m. Both rivers are of similar size with autumn rain and spring snowmelt the key features. The mountains where the rivers rise are tall but are east of the Main Divide and so generally do not receive West Coast rain and as they are a relatively long way from the east coast, any easterly winds carrying heavy rain have lost much of their water burden before reaching the Opuha catchments.

Storage

The lake is 710 ha in area and has 95 million cubic metres of storage. The operating range is 17 m with maximum and minimum levels for generation of 52 m and 35 m respectively. The generator will not be able to operate below the minimum level requiring spill to meet irrigation and minimum flow requirements.

Generation

Average annual energy output has historically been about 30 GWh with a record 36 GWh recorded in year ending March 2001 and as low as 16 GWh in year ending March 2002. Recent changes to the resource consent will reduce spill from 5% to 10% to 1% to 2%. This should increase annual average output to 31 GWh or 32 GWh.

All the electricity produced from the site is exported into the Alpine distribution network, and half of that is exported to the transmission grid. Peak demand within the distribution network is 85MW with approximately a 1% pa growth expected. Total energy demand is expected to grow at 5% pa.

Irrigation

The Opuha irrigation scheme services up to 16,000 ha of farmland. In May 2002, it was reported that all water right allocations had been taken up.

Operation

The project is remotely controlled via telecom lines. Operators' weekly checks include monitoring of dam and providing data for civil engineering review. There are two local operators, one at Fairlie and one at Tekapo. There is also provision for remote laptop dial-in.

The station typically goes through two start/stop cycles per day and has proved to be extremely reliable with very high availability (over 98% in year despite an electronic governor failure and an excitation problem).

TABLE 5.1: **SUMMARY**

COMMERCIAL RATING	EXTERNALITY ISSUES	REGULATORY ISSUES
medium	Irrigation scheme to improve river flows and better the regional farming economy long term.	>5MW rule for generation ownership for non "new renewables".
ENERGY SOURCE	**ENERGY USE**	**CONNECTION**
variable	export	grid

TABLE 5.2: **GENERIC ANALYSIS**

GENERIC CASE	COMMERCIAL ISSUES	EXTERNALITY ISSUES	REGULATORY ISSUES	NEW ZEALAND SPECIAL FACTORS
Hydro	Water priority for generation is secondary to its use for irrigation. Opuha irrigation was not bankable without generation. District water supply scheme is an area of potential – dam outlet & pipeline turbines, retrofit options.	Minimum flow in natural water courses. Wild river preservation. Paternalism – regional strategic growth vs parochialism.	Water allocation – no value placed on water. Long & difficult consenting process – expected that only 10% of potential could be realised for this reason. Excluded under current renewable definition. Conservation orders put resource off-limits.	Climate impacts generally. Irrigation needs. Cultural sensitivity to mixing waters. Water supply schemes match daily demand but not seasonal.

case study 6: windflow wind turbine

BACKGROUND

Windflow Technology Ltd is a start-up wind turbine manufacturing company based in Christchurch and is planning to install its first Windflow turbine at a site near Christchurch. This case study gives a useful insight into the issues associated with resource management planning and connection to a rural network.

DESCRIPTION

Windflow Technology Ltd is planning to enter the wind turbine market with a unique two-bladed, teeter rotor design driving a synchronous generator through a torque-limiting gearbox. This is at variance from conventional wind turbines, which mainly drive asynchronous (induction) generators and/or use power electronics to connect to the electricity network.

Potentially, indigenous manufacture of wind turbines of a novel design able to withstand the more severe wind force in New Zealand will be a beneficial step enabling more power to be obtained economically from this abundant natural resource.

The first Windflow turbine of 500 kW will be sited on Banks Peninsula (Gebbies Pass). The company also has exclusive rights to develop a wind farm at a property on North Range Road, running along the ridge of the Manawatu, close to Palmerston North.

The Windflow path to commercialisation involves two stages. The first stage is to manufacture a single 500 kW, 33 m blade (perhaps larger) turbine to be installed at Gebbies Pass on Banks Peninsula. This is to demonstrate that local manufacturing, using the cost-effective technologies of the Windflow design, will result in lower cost of energy than imported machines. There is no intention of installing further turbines at the Gebbies Pass site.

In the second stage Windflow will manufacture at least six and preferably 10 wind turbines of 500 kW each (perhaps larger). These will be used to market the Windflow and related products and promote further sales. At least six of these turbines are expected to be erected at the Aeolian Property Company's 240 ha site near Palmerston North or some other site.

TABLE 6.1: **SUMMARY**

COMMERCIAL RATING	EXTERNALITY ISSUES	REGULATORY ISSUES
low	RMA application	Technology company demonstrating a prototype windmill Not an energy company
ENERGY SOURCE	**ENERGY USE**	**CONNECTION**
variable	export	grid

TABLE 6.2: **GENERIC ANALYSIS**

GENERIC CASE	COMMERCIAL ISSUES	EXTERNALITY ISSUES	REGULATORY ISSUES	NEW ZEALAND SPECIAL FACTORS
Wind	Proximity to the network. Cumulative capacity constrained (20% of network load). Does not solve capacity constraint.	Area of outstanding natural beauty. Noise and visual impact. Site accessibility.	Shared benefits. Distributors can own unlimited capacity. Can a connection be made into the network at no greater cost than the national grid?	NZ is a small, long, narrow island, in roaring 40's, long coastline. Hydro system backup opportunity favours wind.

case study 7: BP service stations

BACKGROUND

This case study enables an appreciation of the technical and environmental aspects of on-site, photo-voltaic electricity generation interconnected to a network.

Since 1999 BP has progressively introduced solar power to some of its largest service stations in this country. This is part of an international programme launched in 1999, and BP now has almost 400 sites with solar canopies world-wide.

Eleven sites in New Zealand have already been equipped and the plan is to achieve 20 sites by the end of 2002. Each solar-powered service station has between 200 and 500 PV solar panels on the forecourt canopy over the fuel pumps. The systems are interconnected with the mains and have no battery storage. Generally, power is imported as the power demand from pumps, lighting and other loads is in excess of the panels peak output.

BP Solar is the third largest manufacturer of photovoltaic systems globally and the largest outside Japan, and is the world's largest commercial user of PV solar power. It has nine manufacturing facilities globally, located in Maryland, Virginia and California, USA, and in Spain, India and Australia. Output is growing at over 30% per year.

DESCRIPTION

The solar panels form the roof of the forecourt canopy at BP Connect service station and convenience store sites and are an integrated element of the canopy structure. They replace the conventional canopy roof.

The solar panels used in the original BP Plug-in-the-Sun retrofit programme were a crystalline silicon type with a photovoltaic (PV) efficiency of 12-13% under optimal conditions. Papakura MSA was the first site in New Zealand with arrays of solar cells mounted on the canopy (September 1999) and is fitted with this panel type.

The solar power forecourt canopies make use of amorphous silicon thin film panels doped with germanium. They have a PV efficiency of about 6% and are supplied under the BP Harmony programme that commenced in 2000. In New Zealand, 11 BP sites have been fitted with Harmony solar canopies to date and two more (Cambridge and Queenstown) are planned for this year.

Where higher levels of efficiency are of benefit, a third product using BP Saturn technology is available. This is high-efficiency crystalline technology with an efficiency of up to 16%.

BP's solar powered canopy systems are grid-connected, i.e. they interface with the mains power supply rather than providing power from a segregated source. By supplying part of the service station's electrical requirements, they provide a modest saving in electricity costs and reduction in greenhouse gases (CO_2) that would otherwise be emitted due to marginal electricity generation.

The solar power system comprises photovoltaic panels, single-phase inverters and a fault monitoring system. The DC power generated by the solar panels is converted to mains 230V 50Hz AC power by inverters. These are connected direct to the mains at the site main switchboard and operate in parallel with the grid. The solar power system generates a relatively small proportion of the site's overall electrical requirements, so no power is exported to the grid.

The components used for the solar power systems have been standardised for the BP Sunflower and Harmony programmes with the exception of the USA where specific UL requirements apply. The components have been selected so they will form a functioning and productive solar power system whichever country they are used in.

TABLE 7.1: **SUMMARY**

COMMERCIAL RATING	EXTERNALITY ISSUES	REGULATORY ISSUES
low	none	Technology company demonstrating a photovoltaics. Not an energy company. Net metering.
ENERGY SOURCE	**ENERGY USE**	**CONNECTION**
variable	export	grid

TABLE 7.2: **GENERIC ANALYSIS**

GENERIC CASE	COMMERCIAL ISSUES	EXTERNALITY ISSUES	REGULATORY ISSUES	NEW ZEALAND SPECIAL FACTORS
Photovoltaics	High capital cost. Zero maintenance. Solid state	Life cycle costs in terms of emissions not quantified.	No regulatory barriers (no emissions). Buy-back and exit fee.	Winter peak demand - cloudy summers.

case study 8: kumeroa rural farming community

BACKGROUND

This case study gives a useful insight into the issues associated with remote rural communities using local renewable resources, and whether to remain grid connected or to 'island'.

IRL and Massey University have been undertaking a research project on the energy use of a community of six farm properties in Totara Valley, Kumeroa near Palmerston North. Except during the shearing season, electricity consumption on each farm is meagre and farmers pay more in line charges than for the electricity.

The research project has been monitoring energy use and is now looking at the range of on-site opportunities for electricity generation. These include small wind and hydro facilities. The study will also consider the Resource Management Act requirements for small projects such as these.

DESCRIPTION

The small rural community is at the end of a 10 km-long, low-voltage electricity supply line. The distributed generation issues relate to the utilisation of local resources for electricity generation at a remote rural site. The study considers the houses as an aggregate load, and various distributed resources are assessed to determine their value in contributing power to this load, with the surplus energy exported to the grid. This case study draws on this work and specifically focuses on diesel generators, local hydro and wind resources. The properties have been monitored for a year.

TABLE 8.1: **SUMMARY**

COMMERCIAL RATING	EXTERNALITY ISSUES	REGULATORY ISSUES
low	Research project.	Increasing energy costs in the future. High capital cost of connection. Trend among rural people to buy diesel generator sets. Removal of cross-subsidisation, especially rural. 2013 obligation to supply time horizon.
ENERGY SOURCE	**ENERGY USE**	**CONNECTION**
variable	on-site	grid

TABLE 8.2: **GENERIC ANALYSIS**

GENERIC CASE	COMMERCIAL ISSUES	EXTERNALITY ISSUES	REGULATORY ISSUES	NEW ZEALAND SPECIAL FACTORS
Rural region/ community/ dwelling	Cost of connection to the network. Rural supply reliability.	Dependent on chosen technology.	2013 obligation to supply time horizon.	Decline in rural economies.

feedback

CAE welcomes comments on this paper.
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